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ARTICLE

AN APPLICATION OF LEAN THINKING PRINCIPLES IN A LABORATORY OF A HOSPITAL

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ABSTRACT

The hospitals can gain many benefits by applying lean thinking principles. There are many opportunities for hospitals to decrease the costs and to improve efficiency by improving the processes of hospitals throughout lean thinking. In this paper a university's laboratory has been analyzed by lean thinking principles. Within the context of process improvement studies at the central laboratory of the hospital, the process of lean thinking has been examined. There were 20 units in the laboratory and 16500 test results have been reported, with an average of 900 outpatients and 600 inpatients per day. The wastes in the laboratories have been determined, the causes of these wastes have been analyzed and improvements to eliminate the causes of the wastes have been stated. For certain analyzes in various laboratories, the stages of the processes have been examined with a lean point of view. All stages of the processes have been identified and the activities carried out at these stages have been categorized as activities that add value and do not add value. Suggestions have also been made for the removal of activities that do not add value.

KEY WORDS
Lean thinking,
Lean hospital,
Lean Laboratory

INTRODUCTION

In many hospitals, lean thinking principles and tools have been utilized in various parts of the laboratory, including clinical laboratories, blood banks, microbiology and anatomic pathology. Many lean journeys start in clinical laboratories because the test volumes are very high and cycle times are the fastest and they are the most critical areas. Clinical laboratory samples may be delayed in many stages in value streams, such as collection of samples, receipt of samples, or testing sites [1]. The similarities of the laboratories with the production lines are considerable. For this reason, the application of lean manufacturing techniques in laboratories will provide significant benefits [2,3].

There are many studies done in the hospitals to evaluate the applications of lean techniques in healthcare. A study applied in an emergency department of an university hospital showed how lean techniques can be adopted in order to reduce wastes in hospitals [4]. A case study in a clinical laboratory has been done to demonstrate how the concepts of value stream mapping and process optimization can be applied in healthcare[5]. In a clinical laboratory of a super specialty hospital, the lean methodology has been applied to reduce the turnaround time of the clinical laboratory[6]. To examine the application and outcomes of applying all of the seven lean flows to pathology laboratory remodeling as part of a lean rapid improvement, a research has been done [7]. A descriptive cross-sectional study was carried out to examine the level of usage, barriers and enablers, impact of lean tools in the Namibian medical laboratory services. Findings from the survey showed that the perceived impact of lean tools on the medical laboratory industry was positive. Lean tools were perceived as instrumental for the observed improved operational performance, shortened TAT, improved employee motivation and reduced cost [8].

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It is important to understand the objectives and the criteria before starting a lean journey. As the criteria; number of complaints, cost and quality, number of patients on the waiting lists, number of employees, hours worked, patient experience, waiting days, employee morale, turnover times, number of accidents and defects can be defined. Data on the current situation should be collected when the objectives and criteria are decided. In the basic case, collecting data is not always easy. When information can not be obtained from digital platforms, information must be collected manually [9].

After understanding what the value is according to customers, it is necessary to define and analyze the flow of activities in creating the value for customers. In this analysis, all activities and events in delivering the product or service to the customer and the flow of information supporting the activities of value stream are defined.

The main point in lean thinking is to provide flow. All activities are carried out to ensure flow. When examining laboratories with a lean thought point of view, it should be assessed what prevents the flow in the laboratories. From this point of view, when the processes are evaluated, it can be seen that all the waiting times interrupt the value streams. In lean laboratories, it is aimed to deliver the results of the analysis of blood samples to the patients and doctors as soon as possible with minimum resources.

LABORATORY WASTES WITH LEAN THINKING PERSPECTIVE

When the processes in the laboratories are examined according to the lean thinking principles, the wastes seen in the laboratories can be stated as follows;

- Blood samples rejected due to reasons such as the absence of a bar code, the lack of adequate blood samples etc.,

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- Blood samples waiting for the next procedure,
- Blood specimens are transported between sections or equipment,
- Movements, depending on the staff, equipment and walkways between departments,
- Equipment breakdowns,
- Wait for confirmation after blood samples have been analyzed,
- Blood samples waiting in parties,
- Unbalanced workload related to the volatility of demand, which is the characteristic of the process; because of this it is very busy at some hours and the waiting time is high and if the demand is low, the idle capacity is high.

The most important reasons of waste in laboratories are the characteristics of the demand variability, the poor layout, the processing of blood samples as batches, the differences in the cycle times in the process stages, and the difference in cycle time and takt time. In laboratories, waste can occur in processes, depending on the cycle time and the takt time. At any stage in the value stream, the cycle time is greater than the takt time, indicating that the patient requests cannot be met and the waiting times for the patients are unacceptable. For this reason, it is necessary to balance the cycle times in the value stream and not to have a longer cycle time than the takt time.

One of the most important causes of waste arises from workplace arrangements. In laboratories, workplace is usually determined on a departmental basis rather than on employee movements or flow of blood samples. In particular, staff working at night shifts or on weekends can walk between equipment that are very far from each other. As a result, waiting times for blood samples and flow times may increase.

Transferring blood samples as a batch between the centrifuge device or the blood separating device and the section where analysis is performed reduces movement expenditure. However, flow times are increasing due to the increase in waiting times of blood samples between devices.

Workplace layout is crucial in reducing employee's walking needs and distances. A good layout that considers the flow of blood samples has very important implications for eliminating wastes due to staff walkthroughs and reducing the need to move as parties. At the basis of lean thinking, there is a single piece of flow rather than being processed as parties. In the case of processing in batches, the first processed part must wait for the last processed part. This also means that the flow time increases.

AN OVERVIEW OF THE PROCESSES IN LABORATORIES

Polyclinic patients register at the registration desk when they come to the laboratory, than they take barcodes, tubes and their sequence numbers for bloodletting. Blood is taken from the patient in the blood-taking department. Blood samples are collected by pre-laboratory periodically and then they are being recorded, centrifuged and separated by the blood separation device. Relevant laboratories take blood samples separated from the preliminary laboratory at regular intervals and analyze these blood samples. With the approval of the results obtained from the analyses, the process is completed. Barcodes for inpatients are taken at the relevant service center. The personnel collects blood samples from the relevant departments at specific time intervals. They follow the same process as policlinic patients after being recorded in the pre-laboratory phase. Blood samples of emergency patients come from the central laboratory with the elevator and are recorded here. They are then transferred directly to the laboratory and the centrifugation of the blood samples is carried out in the relevant laboratories. Some emergency blood samples can be centrifuged at the pre-laboratory stage after registration. In order to distinguish emergency blood samples from other blood samples, the tubes of these blood samples are in blue color. Thus, the relevant laboratory can quickly identify and prioritize the urgent ones.

LEAN APPLICATIONS IN LABAROTORIES

There are very important opportunities for blood samples to reduce waste and reduce flow times during the collection and separation phase. Significant gains in flow times can be achieved with the reduction of wastes in the process and the improvement of the flow of blood samples.

Evaluation of causes of rejection of blood samples

Rejection of the blood samples can cause important wastes such as to rework, movement, transporting, waiting time. The reasons of the rejection of blood samples have been analyzed to eliminate the wastes. A pareto diagram based on the rejection values of the blood samples from the inpatients is shown in figure 1. As seen in [Fig. 1], the most important reasons for the rejection of blood samples from inpatients are the samples without barcodes. When the samples without barcodes are prevented, the rejection rate of the blood samples coming from inpatients will be reduced significantly.

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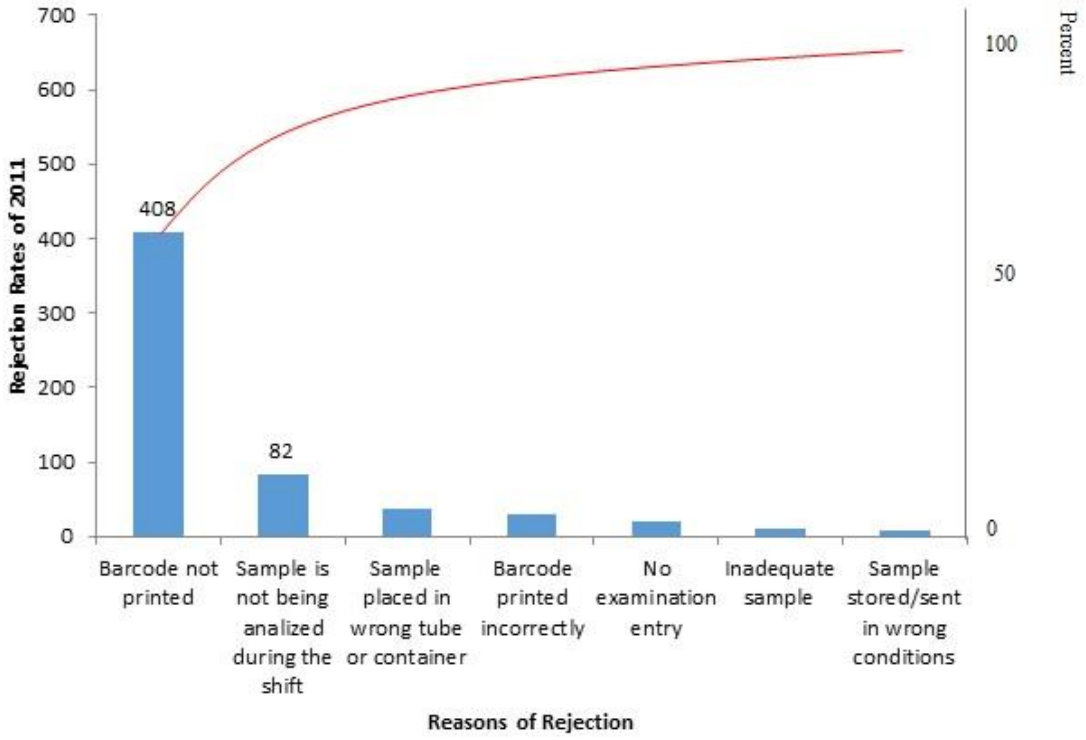

Fig.1: Pareto analysis for the rejected values of blood samples from inpatients.

Reasons of rejection of blood samples from laboratories also examined. The reasons of rejection of blood samples form laboratories can be summarized as;

- Samples with clot,
- Inadequate sample (Hematology laboratory evaluates inadequate samples as inappropriate sample),
- Inappropriate sample,
- Hemolyzed sample,
- Other (sample on the way, not working in that shift, acceptance is not working, false request, technical fault, missing parameter, repetition needed.

By determining the reasons of the rejection of blood samples and finding the ways that cause the rejections of the blood samples in laboratories can provide many benefits on the way of lean journey.

Calculation of mean of number of steps per sample and mean of distance per sample in laboratories

With a lean point of view, walking of laboratory personnel and transportation of blood samples between laboratories and equipment are wastes. In this context, the number of steps per sample and the distance per sample were calculated for the staff under the assumption that there is no difference in walking distances between the blood sample numbers analyzed and between the days of the week and the staff in the laboratory. The number of steps and walking distance of the personnel are calculated; the blood samples are taken from the preliminary laboratory step and carried to the relevant laboratory and the blood samples are loaded on the related equipment. Here, only the average number of steps per sample and the average distance per sample were calculated based on the personnel thought to perform the most walking activity in the laboratory. However, since there is more than one staff member in a laboratory, the average number of steps per sample and the average distance per sample should be calculated by calculating the average number of steps and average walking distance for all staff. The average number of steps per sample and average distance per sample for a staff member in laboratories are shown in [Table 1].

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Table 1: Number of steps per sample and distance per sample in a laboratory

Laboratory	Number of Daily Analysis	Number of daily steps for a staff member	Number of Steps per Sample	Daily Distance for a Staff Member (Meter)	Distance per Sample
Preliminary laboratory	3500	4200	1,2	2980	0,85
Endocrine	450	3243	7,2	2306	5,12
Biochemistry	1200	2587	2,15	1840	1,53
Serology	150	1989	13,26	1414	9,42

Evaluation Of activities that add value to the laboratory or not

For certain analyzes in various laboratories, the stages of the processes have been examined with a lean point of view. In this context, average times (8.00 am - 17.00 pm) were determined for the polyclinic patients and the inpatients from the printing of the barcode to the approval of the results. At each stage, value-added activities and their duration were determined and the percentages of activities that add value and do not add value at were determined.

The stages have been determined as follows;

Sample acceptance period: The time between the printing of the barcode and the acceptance of the blood sample by the preliminary laboratory.
Laboratory acceptance period: The time elapsed between the acceptance of the blood sample by the preliminary laboratory and the acceptance by the laboratory concerned.
Result entry time: The time between the acceptance of the blood sample by the relevant laboratory and the receipt of the analysis result.

Result confirmation time: The time elapsed between the time of the last analysis of the blood sample and the confirmation of the blood sample analysis result.

In [Table 2], the percentage of value added activities for the stages of TSH analysis for policlinic patients in endocrine laboratory and in [Table 3], the percentage of value added activities for the stages of TSH analysis for inpatients in endocrine laboratory have been shown as examples of studies made in the laboratories.

Table 2: Analysis of TSH samples for policlinic patients

TSH Samples	Sample acceptance	Laboratory acceptance	Result entry	Result acceptance	Total
Duration(Policlinic patients	42	100,82	126,04	63,69	332,55
Total duration(%)	12,6	30,31	37,9	19,15	
Duration of the value added activities	5	41	30	1	77
Value added activities(%)	11,90	40,66	23,80	1,57	23,15

Table 3: Analysis of TSH samples for inpatients

TSH Samples	Sample acceptance	Laboratory acceptance	Result entry	Result acceptance	Total
Duration(Inpatients)	95	100,82	126,04	63,69	385,55
Total duration(%)	26,64	26,14	32,69	16,51	
Duration of the value added activities	5	41	30	1	77
Value added activities(%)	5,2	40,66	23,80	1,57	19,97

As shown in tables, 23,15% of activities performed for TSH analysis of polyclinic patients in the endocrine laboratory and 19,7% of activities performed for TSH analysis of inpatients are value added activities.

Reducing waiting times between processes of blood samples

In order to analyze the blood samples separated and centrifuged in the blood sorting equipment, the relevant laboratories go to the preliminary laboratory at certain intervals and blood samples are brought to the relevant laboratory. As seen in the review of the value stream, blood samples from the blood separation device and centrifuged can be waited to be taken from the relevant laboratory. In some cases, the incoming personnel are not able to return blood because they do not have blood samples to be analyzed from the laboratories, and an unnecessary activity has been carried out in the laboratory and preliminary laboratory stage. Waiting is not a value added activity for taking blood samples from preliminary laboratory to the relevant laboratories. It is necessary to reduce unnecessary movements of staff between the laboratory and the preliminary laboratory and the waiting. For this purpose, the pitch

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values between the laboratories and the preliminary laboratory were calculated and shown in [Table 4]. According to these values, it was determined how long the blood samples should be taken between the laboratories and the preliminary laboratory and transferred to the related laboratories. It was accepted that it would be appropriate to carry blood samples in 10 units while the pitch values were calculated.

Table 4: Pitch values for laboratories

Laboratory	The average number of patients between 8.00-12.00	Takt time	Pitch	The average number of patients between 13.00 -16.00	Takt time	Pitch
Endocrine(TSH)	193	1,24	12,4	23	7,82	78,2
Biochemistry(Glukoz)	403	0,59	5,9	49	3,67	36,7
Serology(HBsAg)	39	6,15	61,5	10	18	180
Immunology	13	18,46	184,6	6	30	300
Hematology(HgB)	530	0,45	4,5	92	2,6	26
Coagulation(INR)	125	1,92	19,2	30	6	60

Blood samples are kept in a specific area for retrieval by the relevant laboratory after exiting the blood separation device in the preliminary laboratory stage. In order to minimize the waiting of removal of the blood tubes from the blood collection device, a system (voice warning or a lamp warning) can be established on the blood collection device to inform the laboratory that the blood samples are ready for analysis. Thus, the waiting time can be minimized for blood samples from the blood separation device to be taken from the relevant laboratory.

Patients after registering at the front desk sometimes go to other sections in hospitals, and can come back to give blood 3- 4 hours later. In this case, the time between enrollment of the patient and enrollment of the patient's blood sample in the laboratory can be quite high. If the nurses who receive the blood of the patient have hand terminals, recording the blood sampling time and logging in from this point on the system will make the flow times for the blood samples more realistic. At the same time the staff of the preliminary laboratory stage will not need to register because the registration of the hand terminals and the laboratory entry of the blood sample will be made directly. If the blood sorting device can also make the laboratory record, there will be no need to perform manual recording. Thereby, there will be no need for waiting for the blood to be taken, for waiting to be loaded on the respective centrifuge and blood separating devices after taking the record.

In the laboratories, the workplace is usually organized according to departments and is not performed according to the progress of the blood samples in the process or the movement of the personnel. The distance between the centrifuge and the analysis areas causes the blood samples to be transported in batches. These parts cause delays and prolongation of flow times by reducing movement waste. In laboratories, a rail system can be installed to provide continuous flow to reduce downtime. If all devices are connected to each other with the rail system, the waiting time which is wasted according to the lean thinking can be reduced and the activities in the preliminary laboratory stage can be minimized. Continuous flow of blood samples can be achieved with the devices connected by automation.

The blood samples for analysis show significant differences from the days of the week and the hours of the day. With the cross-work system, division and staff can be supported from other departments during peak hours. When a certain number of patients are waiting for their blood to be taken, support can be provided with additional staff to assist the blood-taking staff.

Measuring flow times

Flow time is a very important indicator in measuring the performance of laboratories. Flow times in laboratories are usually measured by analytical method. It should be assessed from the viewpoint of the customer that the activities add value to the concept of lean thinking. The important point is the time between the patient's applications for blood analysis until the approval of the results. In some cases, although the time for an analysis is low, the duration of another analysis carried out with this analysis can be long. In this case, the length of time that the results reach the doctor depends on the long analysis.

The time elapsed between the receipt of a barcode by a patient and the approval of the test result shown in [Table 5] as an example. As shown in [Table 5], If fT3, fT4 or TSH are present, the analyses prepared in the biochemistry laboratory are waiting for a period of 70% of the completion time of the analysis.

For this reason, it is considered to be more appropriate to evaluate patient-based rather than analysis-based evaluation of flow times with a lean point of view.

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Table 5: Flow times according to TSH analysis

	Without TSH	fT3, fT4 or TSH present
Time between barcode date and date of blood collection	8	8
Time between blood collection and blood separation date	23	23
Time between blood separation date and laboratory acceptance date	66	87
Time between the laboratory acceptance date and the device dispatch date	9	49
Time between sending to device and working date	44	30
Time between work date and approval	21	95
Total time	**171**	**292**

Measuring the leanness of laboratories

There is continuous flow at the base of lean thinking. In order for continuous flow to be achieved, activities that do not add value to the process should be abolished and the wait between the stages in the process should be minimized. The leanness of laboratories can be evaluated according to the proportion of activities that do not add value in the processes. Laboratories will be able to increase the level of leanness to which they can remove unnecessary activities from the process.

In laboratories, the main causes of waste can depend on variability in demand, workplace arrangements, batching and non-transaction of blood samples, cycle time differences in processes, and the difference between cycle time and takt time. An important indicator when measuring leanness is the difference between the cycle times in the value flow and the takt time. Balancing the cycle times of the steps in the value flow and not having the cycle time greater than the takt time is very important in reducing the waiting times of the patients.

The leanness of laboratories can be assessed according to the level of these wastes. Laboratories with low levels of waste will also have a higher level of leanness at that level. In this context, the following indicators can be used when measuring leanness in laboratories;

- Rejected blood samples (the ratio of rejected blood samples during a period to the total blood samples during a period)
- Moving distances of blood samples (the walking distance between the point a blood sample is taken and the equipment blood sample is analyzed)
- Flow times assessed on patient basis (the time between the patient's applications for blood analysis and the approval of the results)
- Value adding activities / Total time
- Centrifugal efficiency
- Batch size for centrifuges, lot sizes for carriage between laboratories, batch sizes for processing in equipment, batch sizes for approval
- Variation level (for lean purposes, one of the aim is to reduce variation, balance the workload and balance the run time and cycle times which is crucial to reduce the variation over time).

CONCLUSION

The main point of lean thinking is to analyze all the activities as value added activities or non value added activities according to the customers' viewpoint. By eliminating the non value added activities, it can be possible to increase the efficiencies of the processes of manufacturing firms and service firms. In this paper, a laboratory of a university hospital has been analyzed according to the lean thinking principles. The wastes of the laboratories have been evaluated and some improvements have been suggested to eliminate the wastes. The waiting of the blood samples between the stages prevents the flow. So it is possible to decrease the flow times by determining the reasons of waiting of blood samples between the stages and to eliminate the reasons of waiting of the blood samples. By analyzing the processes of the laboratories it can be possible to reduce the Waiting times of the patients, to increase the efficiency of the processes, to increase the service quality. There are many possibilities to decrease the waiting of blood samples between the stages with lean thinking principles.

CONFLICT OF INTEREST
None

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