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Toward Lean Hospital through Value Stream Mapping: A Pilot Study in NICU

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Abstract

Introduction: The purpose of this study is to propose a novel waste-finding framework to facilitate implementing Lean hospitals and examine the capability of the framework in a real situation.

Methods: This research utilized a constructive research approach to develop the proposed framework. The data were collected through several sources, including annual hospital performance report, observation and timing using chronometer, and designed forms. The pilot study was conducted in Hazrat Zeinab Hospital in Shiraz city. A total of 15 hospital experts and employees in the NICU of the hospital participated in the study. TOPSIS and value stream mapping (VSM) methods were used to analyze the data. To achieve this purpose, we used MS Excel and eVSM software.

Results: The proposed framework consists of three phases, including (I) selecting a ward, (II) mapping the value stream, and (III) identifying the wastes. To select the ward for implementing Lean initiatives, the criteria are comprised of *bed admission ratio*, *bed occupancy ratio*, *bed turnover*, and *bed turnover interval*. The weights of the criteria are considered 10%, 30%, 10%, and 50%, respectively. The results of the TOPSIS method revealed that NICU was the best ward in the hospital for implementing Lean initiatives. The VSMs of the five main processes of NICU uncovered the wastes, 20 of which were confirmed. They waste approximately 119 man-hours per month.

Conclusion: According to the results, the proposed framework is able to select a suitable ward and uncover the wastes. It implies that Lean efforts must be guided through incremental initiatives.

Keywords: Lean Hospital, Value Stream Mapping, Waste, TOPSIS

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Introduction

Hospitals are considered as a vital element of the healthcare system (1), which struggle to maintain the quality of their services in a wide variety of expertise fields (2). However, they have almost a costly structure (1), leading to decline in their efficiency throughout the world (3). Also in Iran, Rezaei et al. (2019) conducted a meta-analysis study and their results revealed that only 23.7% of hospitals were efficient (1).

The efficiency of a hospital can be improved using Lean philosophy. For example, Castaldi et al. (2016) mentioned that the implementation of Lean in a hospital improved utilization of operating rooms by over 90% and increased the completion of patient processing forms from 30% to 82% (4).

The core capability of Lean philosophy is waste elimination, which increases the value for clients. It is performed by reducing losses and costs and enhancing the quality of services for patients (5). The concept of waste in Lean philosophy is not just defects; it is all the things that absorb resources (time, money, human efforts, etc.) but create no value for the customer (6).

Lean originated from the Japanese manufacturing industry which has been implemented in Toyota (6). Lean production was used as a new scientific term by Krafick in 1988, and it was popularized by Womack, Jones, and Ross in 1990 through their book, "The Machine that Changed the World" (7). Womack and Jones (2003) described Lean as "a way to do more and more with less and less, less human effort, less equipment, less time and less space, while coming closer and closer to providing customers with exactly what they want" (6). Despite the development in Toyota, Lean has also been implemented in a wide variety of industries, such as healthcare (8).

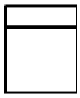
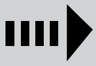
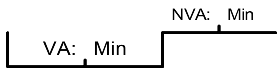
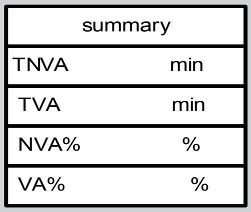
Yahya et al. (2018) revealed that there was no significant difference between the manufacturing and services sector for several Lean tools (9). Therefore, Lean tools can be applied in all organizations to remove the wastes in everywhere (10) and create lean organizations.

Lean hospital refers to "a hospital that is using Lean methods in a systematic way to improve and manage". Lean hospitals proactively identify wastes in all processes and attempt to tackle them to deliver brilliant service, as well as the best medical care (11), using the Lean toolbox.

Value stream mapping (VSM) is considered as a helpful tool in the Lean toolbox. It facilitates analyzing the status quo for identifying the wastes and developing a new state without waste (12). It represents the flow of work and information in a process from the start to the end (13) and makes it easy to understand the process. Activities in VSM charts are divided into three categories, including value-adding (VA), non-value adding (NVA), and essential non-value adding (ENVA) activities (14). VA activities are concerned with satisfying the customer requirements. ENVA activities create no value for the customers, but they are unavoidable because of technical and instrumental issues. In addition, non-value adding activity is considered for any removable waste (15).

VSM is considered as a lean production tool, which aims to document, analyze, and improve the processes to enhance their value to customers (here patients) (16). It is a fruitful method for visualizing and quantifying the complicated healthcare workflows (17). It also provides a common understanding of the flow of processes (18) through uncovering system parameters, such as cycle times, availability, and capacity of resources (19), resulting in a guide for systematic waste searching (20). VSM uses some symbols to show the value stream. Some of the symbols are presented in Table 1.

Table 1: *Some symbols used for VSM*

Symbol	Description
	Process box
	Movement by push
	Delay
	Databox
	Timeline
	Time summary box

As Jimmerson (2017) stated in her book entitled "Value stream mapping for healthcare made easy", the selected processes should meet the following three criteria for creating their value stream (21):

1) Observable: the process must be visible for the mapper (team).

2) Valuable: the process must be worthy for patients and the hospital.

3) High frequency: the process should usually occur and not rarely.

Before selecting the process, it is necessary to limit the Lean project to a pilot study and then expand it. To select the best ward for mapping its value stream, we use TOPSIS.

TOPSIS is the acronym for "technique for order preference by similarity to ideal solution" proposed by Hwang and Yoon (1981) to evaluate m alternatives based on n criteria (22). It belongs to a category of decision making, which is known as multi-criteria decision-making techniques. TOPSIS is considered as the second most popular technique in this category (23). The underlying logic of the technique expresses that the best alternative is found by investigating the distance of each alternative to positive-ideal and negative-ideal solutions (24). In this regard, the best alternative has the least distance to the positive-ideal solution and the most distance to the negative-ideal solution.

TOPSIS algorithm in its original form has six steps (25), which can be encapsulated in the following three stages:

1- Forming the weighted normalized decision matrix:

Given the decision matrix with m alternatives in rows and n criteria in columns, by applying the formula 1 to each column, the normalized matrix will be created. x_{ij} is the value of alternative i in criterion j.

$$n_{ij} = \frac{x_{ij}}{\sqrt{\sum_1^m x_{ij}^2}}$$

By multiplying the weight of each criterion by the normalized values of the criterion, the weighted normalized matrix will be created and denoted as *v*.

2- Calculating positive and negative ideal solutions denoted as A^+ and A^-, respectively:

There are two types of criteria, including benefit criteria (their higher values are better (shown by h)) and cost criteria (their lower values are better (shown by i)). For benefit criterion, the positive ideal solution is defined as the highest values of the criterion in the column and the negative ideal solution is defined as the lowest values of the criterion in the column. For the cost criterion, there is an adverse relationship between them.

3- Determining the distance to positive ideal solution and negative ideal solution and decision criteria:

The distance of each alternative to the positive and negative ideal solutions will be calculated using the following formulas:

$$d_i^+ = \sqrt{\Sigma_{i=1}^n \left(v_{ij} - v_j{}^+\right)^2}$$

$$d_i^- = \sqrt{\Sigma_{j=1}^n \left(v_{ij} - v_j{}^-\right)^2}$$

The decision criterion is calculated using the following formula. The higher the criteria, the better

$$C_i = \frac{d_i^-}{d_i^- + d_i^+}$$

The purpose of this research is to develop a scientific framework (protocol) for finding the wastes. It also tests and reports the application of the framework in a real situation.

Methods

The research methodology used in this research is "constructive research approach (CRA)". Kasanen (1993) stated that CRA is a suitable methodology for constructing a practical framework in a real situation. It consists of six steps (26):

1) Discovering a suitable researchable problem, 2) Understanding the problem and related area, 3) Creating a solution idea, 4) Testing the usefulness of the solution, 5) Reviewing the theoretical basis of the solution, and 6) Recognizing the applicable scope of the solution.

The developed framework for the problem of ambiguity in the way of finding wastes is shown in Figure 1. To test the framework, we conducted a pilot study in Hazrat Zeinab Hospital in Shiraz city.

The framework contains four phases. In the first phase, the most appropriate ward must be recognized for the hospital. In the second phase, the main processes must be mapped for the selected ward

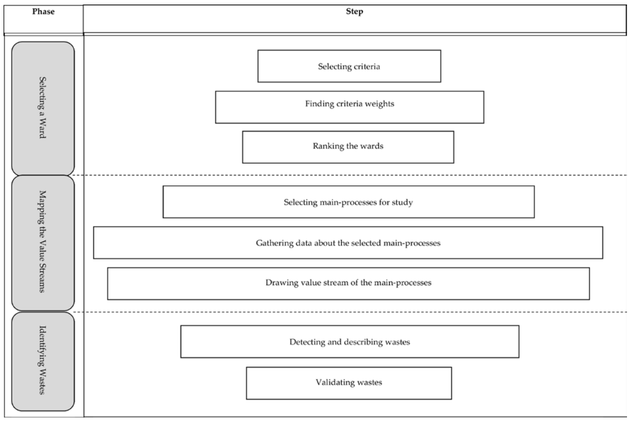


Figure 1: The framework for finding the waste

based on the VSM standard. In the third phase, the wastes were identified for the mapped processes.

Phase 1: Selecting a Ward

In the first step, the experts who participated in this research agreed with the four performance criteria for comparing the hospital wards. The criteria comprised of bed admission ratio, bed occupancy ratio, bed turnover, and bed turnover interval. The values of the criteria were extracted from the published annual hospital performance report. Then, their weights were determined by averaging the experts' opinions, and using a form containing the criteria with blank weights. Table 2 displays the list of the experts who participated in this research.

The decision matrix was formed for the hospital wards using the selected performance criteria. Then, the priority of the wards was determined by following the standard three-step procedure of the TOPSIS method, and the first ward was selected for the next phase.

Phase 2: Mapping the Value Stream

The second phase was focused on evaluating the processes of the selected ward based on the Jimmerson criteria, including observability, value, and frequency. This evaluation was performed using a simple questionnaire filled by experts. Based on the questionnaire analysis, all five processes that were observable, valuable, and highly frequent were selected for the next step. In the next step, the authors mapped the processes by following the next stages:

Stage 1: The data collection form was prepared. The form contained a start and end point boxes, empty space for noting unpredictable events, and problems of the process.

Stage 2: The start and end point were determined for each process, and a time measurement unit was selected, which was *minute* in this study.

Table 2: List of participating experts

Row	Expert Position
1	Hospital Manager
2	Hospital Deputy Manager
3	Quality Improvement Manager
4	Director of Nursing Services
5	Director of Health Information
6	Statistics Expert
7	Supervisor of NICU
8	Head Nurse of Post-cesarean Care Unit
9	Head Nurse of Pregnancy Care Unit
10	Head Nurse of Women's surgery Unit
11	Head Nurse of AICU
12	Head Nurse of Maternity Unit
13	Head Nurse of Phototherapy Unit
14	Head Nurse of Neonatal Unit
15	Head Nurse of NICU

Stage 3: By direct observation of the processes and timing with the stopwatch, the form was completed for at least 30 samples per process. The first author of this paper performed it.

The value streams were mapped for the five processes using Electronic Value Stream Mapping (eVSM) software. For a process, non-value added time was assigned to the idle time or the time of an activity that was not aligned with the goal of the process.

As an example, the description of the sampling process in the NICU is as follows:

According to the physician's order for a sampling of the admitted newborn, the nurse prepares the necessary supplies. Then, she writes the newborn's name and sampling date on a label and pastes it on the sampling container. Afterwards, she washes her hands, wears gloves, places the newborn in the right position, and performs the sampling. She immediately transfers the sample to the container and conveys it to the sample store place; then, she puts the infected single-use supplies into the trash. When the sampling process is finished, the employee in charge calls to the mobile messenger for sending the samples to the laboratory. Thereafter, she records the sample information in HIS and records the observations and actions in the nursing sheet.

Phase 3: Identifying the Wastes

The last phase dealt with detecting the wastes. To achieve this purpose, we explored the value stream maps and determined the problematic points. If the points do not add value to the patients but take time, energy, or money, then they will be considered as wastes. Then, the type of wastes was recognized. To perform a basis for comparing them, all wastes in services were stated based on the time taken by the nurses (or employees).

Finally, to obtain the support from process participants and managers, the wastes which were found were shown to them, and they could either approve or reject some of them.

Results

The annual performance report of the hospital is a good source for opting criteria and determining their values in ward selection. According to the experts' opinions, the suitable criteria consist of *bed admission ratio*, *bed occupancy ratio*, as well as *bed turnover*, and *bed turnover interval*. Also, the experts offered that the weights of the criteria were considered 10%, 30%, 10%, and 50%, respectively.

To select a ward for the study, we applied TOPSIS using MS Excel software. TOPSIS is a simple and explainable method for hospital employee and managers. Table 3 shows the required information for the method. The second column to the fifth column, except the two last rows, represent the weighted normalized decision matrix. The last two rows indicate the ideal solutions. The sixth and seventh columns represent the distance to the positive and negative ideal solutions. The eighth column shows

Table 3: TOPSIS information for selecting the best ward of the hospital based on the four performance criteria

Criterion / Ward	Bed admission ratio (h)	Bed occupancy ratio (h)	Bed turnover (h)	Bed turnover interval (i)	d^+	d^-	C_i	Rank
AICU	0.015	0.176	0.015	0.098	0.175	0.145	0.455	6
Maternity ward	0.087	0.173	0.087	0.035	0.094	0.233	0.712	2
Neonatal 1	0.014	0.109	0.014	0.229	0.306	0.009	0.029	8
NICU	0.008	0.244	0.008	-0.026	0.112	0.289	0.720	1
Phototherapy	0.021	0.151	0.021	0.099	0.182	0.137	0.429	7
Ward 2	0.023	0.163	0.023	0.075	0.159	0.164	0.507	4
Ward 3	0.021	0.193	0.022	0.047	0.129	0.201	0.608	3
Ward 4	0.017	0.171	0.017	0.089	0.169	0.153	0.474	5
A^+	0.087	0.244	0.087	-0.026				
A^-	0.008	0.109	0.008	0.229				

the similarity to the worst condition, and based on the results of this column, the rank of each ward is presented in the last column. The results of the TOPSIS method revealed that the NICU was the best ward for the study.

In NICU, based on Jimmerson's criteria, five processes were considered for candidates of mapping their value stream, including the process of admission, suctioning, sampling, change shift, and discharge of the newborn. All the processes were mapped. For instance, the VSM is shown for the sampling process in Figure 2.

All idle times and spent time unaligned with the process goal were counted as the non-value added times. The process lasted 47 minutes; however, only 30% of the time was considered as the value-added times

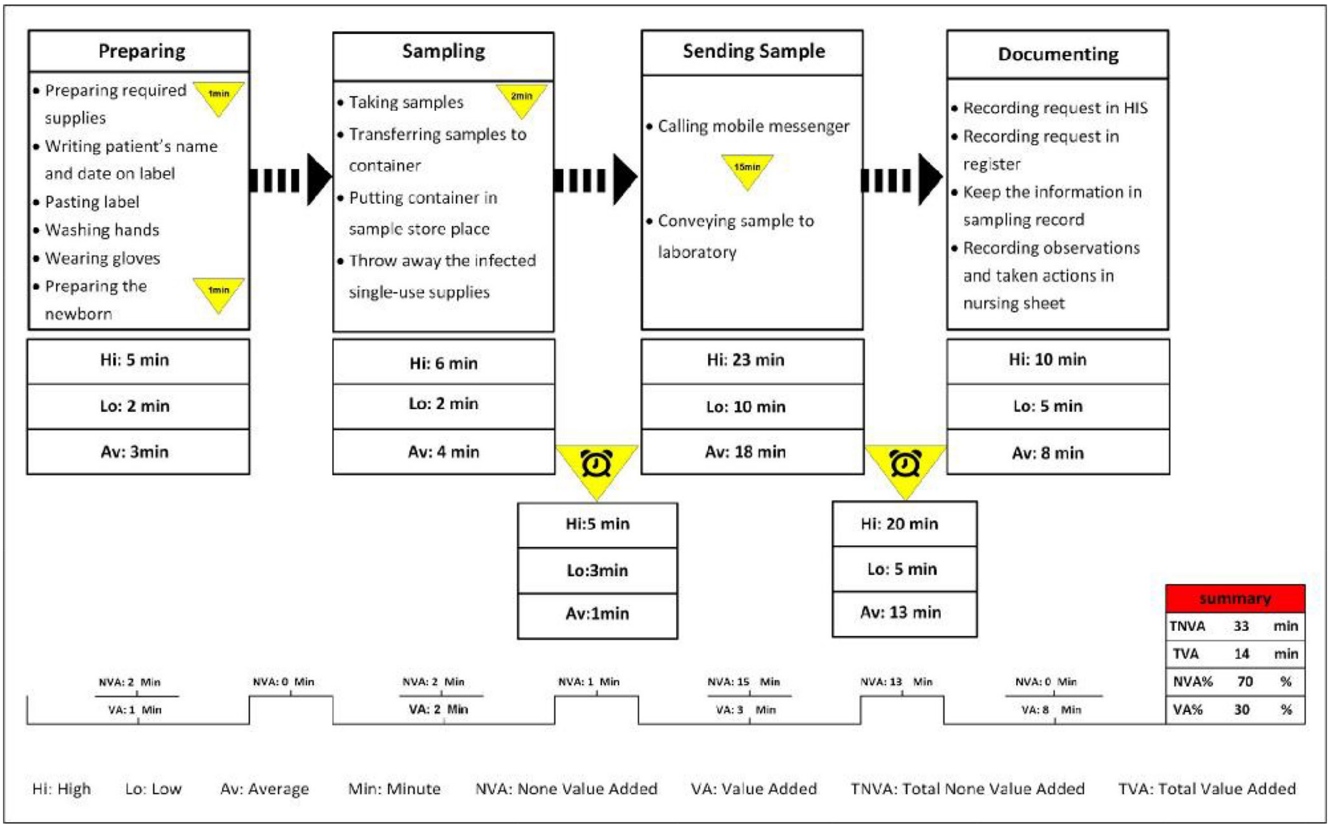


Figure 2: VSM of the Sampling Process

Table 4: Recognized wastes in the sampling process

Sub-process	Waste Title	Waste Type	Time (Minute)	Confirm
Preparation	Waiting for preparation of equipment	Waiting	2	Yes
Sampling	Repeating sampling because of insufficient blood or failing in finding the vein of infant	Defect	1	Yes
Sending a sample to the laboratory	Repeating calls for knowing the name of mobile messenger	Over-processing	4	Yes
	Waiting for arriving mobile messenger	Waiting	10	Yes
	Waiting for starting the process of conveying sample to the laboratory	Waiting	1	No
	Waiting for the mobile messenger to complete the sampling of newborn	Waiting	2	No
Documenting	No waste was found.	-	-	-

Table 5: Statistical characteristics of the wastes in NICU main-processes

Process	Number of Wastes	Time of Wastes (minute)	Frequency of Wastes in a Day	Waste Type
Admission	6	33	22	Waiting, Defect
Suctioning	6	16	25	Waiting, Motion, Defect, Over-processing
Sampling	4	17	14	Defect, Waiting, Over-processing
Change shift	3	6	17	Defect, Motion
Discharge	1	5	1	Waiting

The value stream map and collected data through observations were the two sources for identifying the delays and problems, which are recognized as wastes. The found that the wastes were traditionally categorized into seven groups. To confirm the wastes, the participating nurse(s) and the manager in the process scrutinized the wastes which were found and confirmed some of them. Table 4 shows the list of all the wastes found for the sampling process. The consumed time is the average of 30 observations. Table 5 displays the results of analyzing the status quo for the main processes in the NICU.

Discussion and Conclusion

This paper proposes a method for prioritizing wards for implementing lean practice in them and evaluating the processes. This procedure leads to creation of VSM for the processes and extraction of their wastes. This research demonstrated that the amount of non-value adding activities was 70% in the sampling process. This issue means that most of the efforts in the process are waste. Based on the research, there are five processes in NICU, encompassing 9 waiting times, 6 defects, 3 motions, and 2 over-processing wastes. The wastes approximately waste 119 man-hours per month.

These wastes may be the symptoms of poor coordination in processes and disorders in the workplace, which can be removed by redesigning the processes and implementing 5S technique.

The high frequency waste in the previous studies (e.g. Castaldi et al. (2016)) was “waiting”. In this research, 45% of the wastes were associated with “waiting”. It is the most frequent waste among them. Most of the studies in Lean hospitals focus on the emergency ward. A few of them studied the NICU.

The findings are limited to a NICU ward, and, therefore the generalization of the results should be followed by consciousness. Direct observation can cause a change in the nurses’ behavior in the hospital. We did not fix this variable.

Future studies are recommended to find ways for removing the wastes and design new processes, which are wasteless. Another suggestion is that research should focus on implementing other multi-criteria decision-making techniques in the context of the lean hospitals.

Conflict of Interest: None declared.

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