

Reducing Stock-out Incidents at a Hospital Using Six Sigma

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Abstract—In managing healthcare logistics, cost is not the only factor to be considered. The level of items' criticality used in patient care services plays an important role as well. A stock-out incident of a high critical item could threaten a patient's life. In this paper, the DMAIC (Define-Measure-Analyze-Improve-Control) methodology is used to drive improvement projects based on customer driven critical to quality characteristics at a Jordanian hospital. This paper shows how the application of Six Sigma improves the performance of the case hospital logistics system by reducing the number of stock-out incidents.

Keywords—Criticality level, Healthcare, Logistics, and Six Sigma.

I. INTRODUCTION

SINCE Six Sigma came to life late 1980's, it raised a war on waste by minimizing number of defects and eliminating none value added activities. Initially, Six Sigma tackled manufacturing and production issues and typical improvements included items such as: increasing throughput, minimizing defect rate, increasing efficiency, and decreasing operational cost, etc. These performance indicators are all manufacturing related.

It did not take a long time for researchers to notice that the soul of Six Sigma can be applied in service type industries but with little tweaks to the original method. Many authors even wrote books about the use of Six Sigma for service. Examples of these include; Service design for Six Sigma [1], Lean Sigma for Service [2], and Lean Six Sigma Logistics [3]. Six Sigma thrives on processes, and if we look at any service as a combination of processes, then we can use Six Sigma.

Unfortunately, the statistical strength of Six Sigma is considered a drag in some service applications, since many processes are not automated as in manufacturing environments. For example, trying to calculate the performance indices C_p or C_{pk} for a manual process might be useless. This fact made some authors believe that Six Sigma has not been very efficient for services and supply chains [4]. On the bright side we can say that Six Sigma has many tools in its tool box and while some of these tools may not be very efficient, such as C_p and C_{pk} , others are very efficient. The

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challenge becomes, selecting the proper tools and using them in a proper manner to maximize the benefits of using Six Sigma.

In the area of Logistics and supply chain, literature revealed few publications here and there. There are more articles written in the area of supply chain than in Logistics. Each article focuses on one aspect of these services such as inventory management, delivery time, replenishment rate, etc. The application of Six Sigma in healthcare logistics or healthcare supply chain has seen very little attention. A good review of healthcare supply chain applications, including Six Sigma, is listed in McKone-Sweet et al [5]. The article also revealed barriers and obstacles facing improving healthcare supply chain management. Mingzhou J. et al [6] present a detailed case study of using Six Sigma and lean thinking in designing and operating a healthcare logistics centre in North Mississippi. Heuvel, J.V.D. et al [7] reveal the extensive use of Six Sigma in a hospital in the Netherlands. Craven, E.D. et al [8] reveal the use of Six Sigma methodology in NY hospital in various departments and activities including logistics and supply chain. Guinane and Davis [9] reveal various ways Six Sigma can be used in hospitals. While this paper does not talk specifically about healthcare logistics and supply chain, it does list various tools that can be used in such applications.

In the next few sections we provide short review of basic elements of Six Sigma, supply chain management and logistics. We then review what is special about healthcare logistics, and provide our vision to how Six Sigma can tackle healthcare logistics issues.

II. REVIEWS

A. Six Sigma Review

In 1988, Motorola came out of its greatest woes and became the first recipient of the Baldrige National Quality Award, formally presented by President Reagan. Motorola had achieved one of the most dramatic corporate comebacks in a relatively short period of time. Much of the success was attributed to Motorola's crusade for quality, which spawned its now famed Six Sigma initiative [10]. Following the footsteps of Motorola, General Electric saw great improvement on various processes using Six Sigma.

Six Sigma is a management and quality improvement program that works to reduce the number of defects to as low as 3.4 parts per million. It uses the normal distribution and strong relationship between product nonconformities, or defects, and product yield, reliability, cycle time, inventory,

schedule, etc. [11].

Six Sigma runs through five phases; in the Define phase, the project is fully defined, the problem statement is defined, team is formed, and the project charter is developed. This phase is followed by the Measure phase which maps the process, collects measurements for the related critical-to-quality (CTQ) features, establishes performance standard for measurement scheme and determines the process capability for the base line or as-is process. The third phase is Analyze, which benchmarks the process under study, establishes relationships based on the data collected and determines root causes for the issue under consideration. The Improve phase studies different alternatives to change the process and assesses the risk in each alternative. It changes the process permanently using the best alternative on hand; it then validates the benefits of process change. Lastly, the Control phase implements a set of controls that will guarantee the process will not go back to its old unhealthy state.

The main strength of Six Sigma is that it builds a strong organizational structure that ensures sustainability and success of all future projects. This structure consists of Six Sigma Green Belts, Black Belts and Master Black Belts along with team leaders and champions.

B. Logistics and Supply Chain Management Review

Many believe that competition is not just between companies but between supply chains. The effective and efficient supply chain management is critical for a company to stay competitive. Supply chain management (SCM) is defined by the Global Supply Chain Forum as “the integration of key business processes from end user through original suppliers that provides products, services, and information that add value for customers and other stakeholders” [12].

Logistics is the major element of SCM. The Council of Supply Chain Management Professionals (CSCMP) [13] defines logistics as “that part of the supply chain processes that plans, implements, and controls the efficient, effective forward and reverse flow and storage of goods, services, and related information between the point of origin and the point of consumption in order to meet customers’ requirements”. The prime objective of logistics is to ensure that materials and products are available at the right place, at the right time, and in the right quantities to satisfy demand or customers and to give a competitive advantage to the company.

Logistics has received great attention in the literature which covered the following areas: warehousing and facility location, inventory control, transportation/routing and scheduling, demand forecasting, production planning, and logistics system design. A thorough methodological review of SCM and logistics research is provided by Sachan and Datta [14]. Their review provides an understanding of the current state of research in the disciplines of SCM and logistics.

C. What is Special about Healthcare Logistics?

A typical healthcare supply chain consists of three echelons: healthcare provider, distributor, and product manufacturer

which are linked together via information, material and cash flows as shown in Fig. 1.

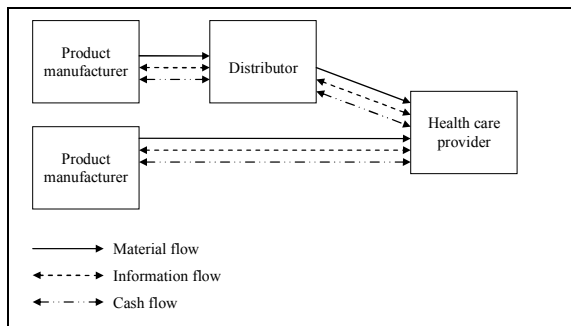


Fig. 1 A typical healthcare supply chain

Logistics management involves managing the activities of purchasing, inventory control, warehousing, and transportation. Each of the indicated logistics activities demands some kind of decision making regarding cost of operations and availability of product.

Logistics activities for commercial commodities tend to focus on optimizing the cost aspect. This is also an important factor in healthcare logistics; however, stock out condition is just as important since it deals with the availability of medical supplies or medicine. This paper classifies medical commodities into categories based on its criticality level to hospitals and patients. It also determines cost level and the performance level for medical commodities.

III. PROPOSED FRAMEWORK

Healthcare logistics cares about cost and customer satisfaction just like any other logistics system, the criticality level of an item affects how we treat this item. For example, for an item that is deemed critical, we do care about the expenses of procurement, storage and transportation of such item. Cost optimization tends to minimize the amount we have on hands. On the other hand, we would like to ensure not having a stock out condition, especially for critical items. This tends to make us planning to have too much of this item on hand. The two competing objectives have to be satisfied in a manner that minimizes the cost while guaranteeing no stock outs. An item with low criticality level will be treated differently due to the fact that alternatives are usually available. So, for a Six Sigma project focusing on healthcare logistics, the objective can be minimizing the total logistics cost, but this has to be constrained with the stock out and availability of alternatives.

In the define phase, when selecting a project we define Importance Index (II) as follows:

$$\text{Importance Index} = \frac{\text{Criticality Rank} * \text{Usage Rank}}{\text{Performance Rank}} \quad (1)$$

IV. CASE STUDY

Our case study organization is a general hospital from the private sector in Jordan. The following sections discuss in detail the application of the different steps of the proposed framework in Table I at the case hospital.

A. Define Phase

The define phase contains four steps as follows:

a) Fully define the process

Hospitals main activities are directly related to providing healthcare, to curing the patients such as prevention, diagnosis, preparation, intervention, rehabilitation and maintenance. Nevertheless, these main activities could not be done without the support activities. Supply chain and logistics are one of the main supporting activities.

If the supply chain doesn't work correctly; the medical supplies will not arrive to the patient, and all related activities of a hospital will not be developed properly. This makes supply chain and logistics extremely important. The main activities in a logistics system at a hospital are limited to warehousing, inventory and transportation. In this step the logistics system of the case hospital is fully defined after interviewing the people concerned.

b) Define the parameters that will be used to assess performance of the process

After reviewing the current process at the warehouse, some Critical to quality parameters are specified. These CTQ parameters are used to assess the performance of the logistics system. The CTQs are divided into two main categories: those which are related to external supplier and those related to internal issues of the logistics system.

In order to perform the assessment it is important to know the most critical parameter from the customer point of view (the warehouse managers). This was done using a questionnaire to get the Voice-of-Customer (VOC).

After validating the questionnaire and making sure that it contains all the possible CTQs, it was distributed among six warehouse managers at the case hospital. The data were then analyzed and the average for each CTQ parameter was calculated as shown in Table II.

TABLE II
AVERAGE RANKING FOR PERFORMANCE CTQS

No.	CTQ Parameters	Average Ranking
1	On time delivery	3.7
2	Actual time for stock replenishment	3.3
3	Suppliers' reliability	3.8
4	Transporting cost	1.3
5	Product Quality	4.7
6	Average inventory level	3.0
7	Shelf life	2.0

8	Number of stock-out incidents	4.0
9	Number of expired items	2.5
10	Inventory holding cost	1.5
11	Total logistics cost	3.0
12	Safety Stock level	3.8
13	Effect of redundant purchase	3.7
14	No. of error in medical items report	2.8
15	No. of products damaged in handling or delivery	2.5
16	No. of incorrect invoices	2.8
17	No. of errors in a bill	2.5

c) Define the Parameters that will be used to assess criticality level of the product

Another questionnaire was conducted to determine the potential criteria for assessing the criticality level of the medical supplies. After validating the questionnaire and making sure that it contains all the possible parameters, it was distributed among six inventory managers, two doctors and four nurses at the case hospital. After averaging the results, it shows that the "effect of stock-out incidents or problems caused by stock-out condition" has got the highest average ranking. Accordingly, this parameter will be used to assess the criticality of medical supplies. Results are in table III below.

TABLE III
AVERAGE RANKING FOR CRITICALITY ASSESSMENT CRITERIA

No.	Suggested criteria	Average Ranking
1	Availability of product in the nearest distributor or manufacturing warehouse	3.9
2	Time needed to get product from the nearest distributor warehouse	4.5
3	Number of alternative products in the hospital or local market	2.9
4	Effect of stock out incidents or problems caused by stock-out condition	4.7
5	Ease of acquiring the item during diagnosis or operation from store	3.8
6	Accessibility of item at store after working hours	4.0

d) Define project goals

The goal of the project can be stated as: to improve the performance of the logistics system at the case hospital by minimizing the number of stock-out incidents of medical supplies.

B. Measure Phase

The measure phase encompasses three main steps:

a) Map current process

This step is based on the information presented in the define phase about the definition of the logistics process. Fig. 2 shows the logistics process map in the case hospital.

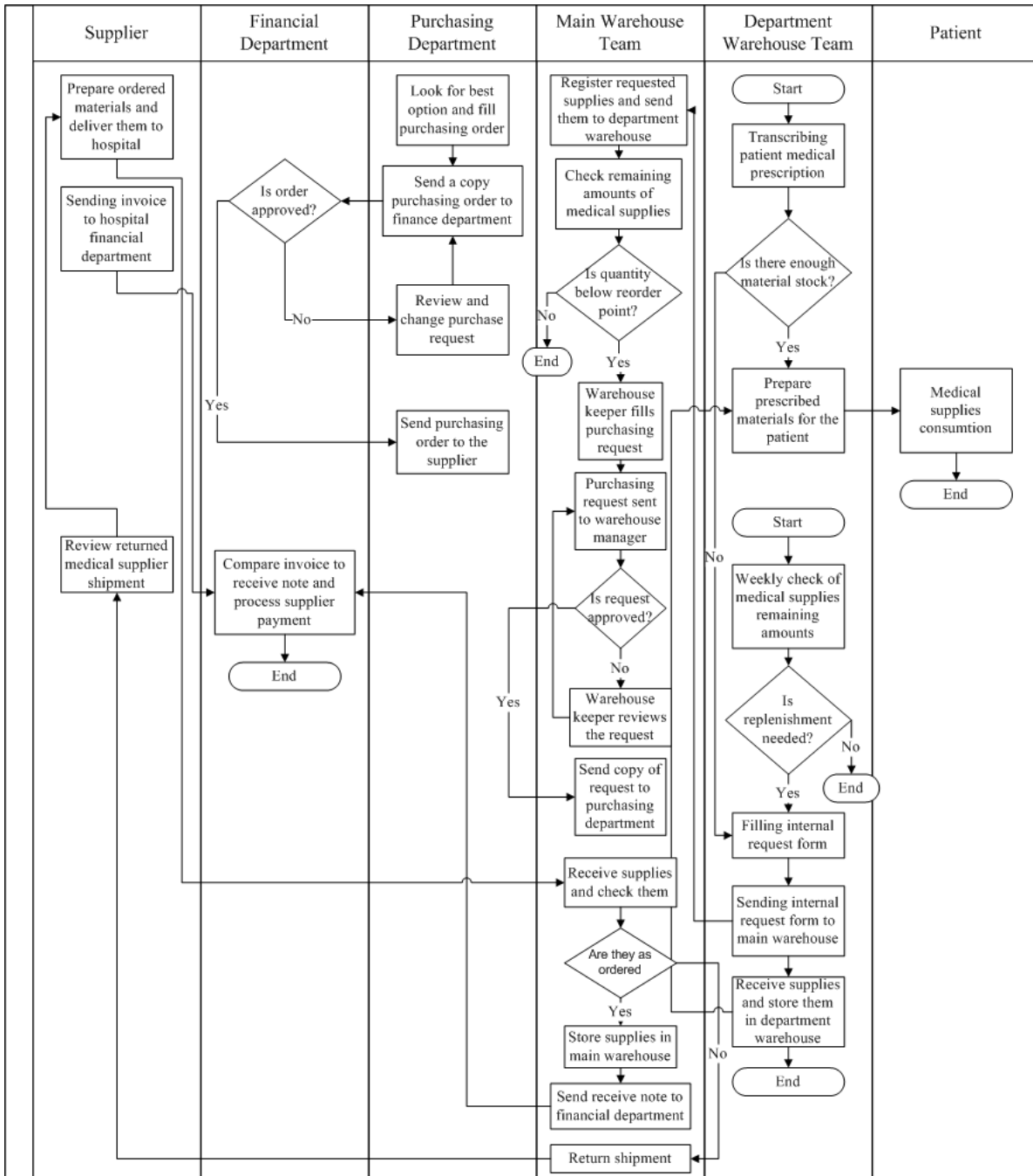


Fig. 2 Logistics process map for the case hospital

b) Measure process' performance parameters

Since the number of stock-out incidence was chosen to be the most important CTQ to the customers, in this step the performance of this CTQ will be assessed.

Due to confidentiality; the performance parameter for all medical items had been measured by the material manager. This was done by reviewing how many times each medical item had been out of stock during the last year. The material manager was asked to rate the performance of each item

according to a scale from 1 to 10; such that 1 indicates high performance, 5 indicates medium performance and 10 indicates low performance.

c) Measure process' criticality parameters

During this step, the criticality of all medical items is assessed by the materials manager. The criticality is assessed according to the results of step 3 in phase 1 which states that the most important factor for assessing criticality is the effect

of stock-out incidents or problems caused by stock-out condition.

The material manager was asked to score each medical item in terms of its criticality to the patients. A scale from 1 to 10 was used; such that 1 indicates low criticality, 5 indicates medium criticality and 10 indicates high criticality. High critical means that the effect of stock-out situation on the patient is highly threatening, while low critical means that there is no threatening effect on the patient.

C. Analyze Phase

The analyze phase involves three main steps which are:

a) Minimize/eliminate non-value added activities

Here we need to determine the non-value added activities so as it can be eliminated or the whole process may be re-sequenced to eliminate the waste. Since our focus in this paper is on the development of the importance index concept, this step was not done.

b) Develop correlation between criticality and performance parameters

According to the goal of this Six Sigma project which is to improve the performance of the logistics system at the case hospital, this step concentrates mainly on finding the correlation between the performance and criticality parameter and shows how they are connected.

Important Index (II) is used to find the correlation between the performance and criticality parameters. The formula below indicates how the Importance Index (II) will combine the two parameters.

$$\text{Importance Index} = \frac{\text{Criticality Rank} * \text{Usage Rank}}{\text{Performance Rank}}$$

Usage rank was measured for each medical item by the materials manager according to the units and cost.

Accordingly, and after the three parameters were assessed for all medical items, the Importance Index was calculated for each item. The Importance Index may range from 1 to 1000, such that 1 is for items with low criticality, low usage and high performance and 1000 is for items that has high criticality, high usage and low performance. The items that have problems are those with low performance and high criticality which means that the items that have higher Importance Index is the most important one and should be considered carefully in the next steps.

Table IV shows the items with the highest value of Importance Index and their corresponding Performance Rank, Usage Rank, and Criticality Rank.

TABLE IV
IMPORTANCE INDEX RESULTS

Medical Item	Performance Rank	Usage Rank	Criticality Rank	Importance Index
Jell Ultrasound	5	5	1	25
Custom Pac Child	1	10	5	50
Prolene 3/0 25 mm	1	10	10	100
Eye Cover for Laser	10	1	1	10
Circuit Anastasia Adult	10	1	10	100

c) Determine potential causes for the problem on hand

According to the results of the previous step, the causes of high Importance Index of both “Prolene 3/0 25 mm” and Circuit anastasia Adult will be determined. To do so, a brainstorming session was held with the materials manager at the hospital.

The “Prolene 3/0 25 mm” is very important item used by the physicians in the hospital and hence it is a critical medical item that must be considered carefully.

The high value of Important Index for the “Prolene 3/0 25 mm” is due to the high criticality and high usage value of it as shown in Tables III and IV.

A cause-and-effect diagram (shown in Fig. 3) was developed during the brainstorming session to summarize the possible causes of having a high criticality and high usage value of “Prolene 3/0 25 mm”, which are:

- Problems with suppliers, such as lateness and nonconformity to the specifications.
- High demand; since it is the preferable item by the people concerned.
- Unavailability of a substitute for this item; as the physicians prefer it and ask for it.

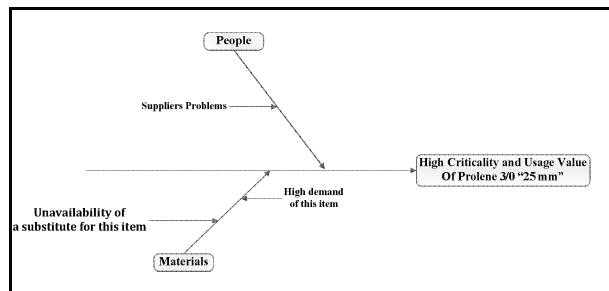


Fig. 3 Cause and effect diagram of the high criticality and usage value of “Prolene 3/0 25 mm”

Circuit Anastasia Adult is also a very important item used by the physicians in the hospital. The high value of Importance Index for the “Circuit Anastasia Adult” is due to the high criticality and low performance of it as shown in Tables III and IV. Also, a cause-and-effect diagram (shown in Fig. 4) was developed during the brainstorming session to summarize the possible causes of having low performance of “Circuit Anastasia Adult”.

Low performance of Circuit Anastasia Adult may arise

from:

- Problems in filling the compensation statement and reflecting it to the software.
- Problems with suppliers, such as lateness and nonconformity to the specifications.
- Problems in material handling of the medical items when moved from one place to another.
- Problems in calculating the number of stock for the item that is available at any time.
- Problems in determining the re-order point and the ordered quantity, as there is no scientific method used to calculate and they estimate it according to their experience.
- Problems in the software they use to update the amount used so far.
- Some problems in stocking conditions, which may make the item ineffective.

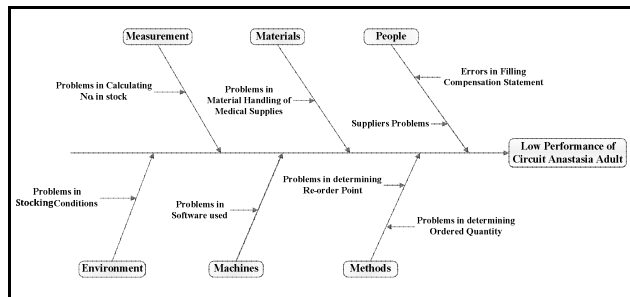


Fig. 4 Cause and effect diagram of the low performance of "Circuit Anastasia Adult"

D. Improve Phase

The improve phase includes one main step which is to implement the new proposed improved process.

a) Implement the New Improved Process

Through this step, suggestions to solve the causes mentioned in the last step of the analyze phase will be proposed.

Regarding the first item: "Prolene 3/0 25 mm"; the suggested solutions to high criticality and usage values are as follows:

- Problems with suppliers can be solved by dealing with more than one supplier and the best one.
- High demand results from the fact that it is the preferable item by the people concerned. So, the managers in charge should consider the quantities of this product carefully and take all the required actions to protect this product from being exposed to damage.
- Another substitute for this item must be found and tried by the physicians

For Circuit Anastasia Adult; the suggested solutions to low performance are as follows:

- Problems in filling the compensation statement must be considered carefully and there must be a new procedure to

make sure that the correct amount used is recorded to prevent stock-out.

- Suppliers problem may be solved by finding other suppliers
- Problems in material handling of the medical items when moved from one place to another, the management may change their way of handling the materials when delivered to the departments.
- Since the inventory management system is not fully automated and humans are involved in the process; sometimes errors in counting the number of units available in the warehouse may occur. This may results in stock-out of this item which will affect the ability of the physicians to accomplish their tasks. The system must be fully automated in order to prevent any human errors.
- The management at the warehouses does not follow any scientific method in calculating the re-order point, ordered quantity and safety stock level. They estimate them depending on experience; this will affect the criticality of the item as stock-out may occur. So, re-order point, ordered quantity and safety stock must be calculated according to scientific methods.
- The software used by the physicians and nurses must be updated to include the calculations of re-order point, ordered quantity and safety stock level according to a scientific method.
- There are some problems in the warehouses, which affect the sustainability and suitability of the medical items.

E. Control Phase

The main aim of this phase is to implement a set of controls that will guarantee the process will not go to its old unhealthy state after a period of time.

This phase was not the focus of our project and so we just recommended that the material management department follows up with the warehouse staff and concerned people to ensure that they are following correctly the adopted solutions- in case any suggested improvements have been implemented.

V. CONCLUSIONS AND FUTURE WORK

This paper opens the door for a promising research in the area of Six Sigma applications in healthcare logistics. The paper introduces a new concept of selecting areas for improvement and improving healthcare logistics based on the concept of importance index. We also developed a framework revealing how this index changes the typical DMAIC methodology especially in the Define and Analyze phases. Future work can validate the importance index concept by applying it in different hospitals in various parts of the world.

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