Penerbit Akademia Baru

Journal of Advanced Research in Business and Management Studies

Journal homepage: www.akademiabaru.com/arbms.html
ISSN: 2462-1935

Deployment of Lean Six Sigma in Strategic Inventory Management

Open Access

Noor Azam Md Saad[1,*]

[1] Razak School of Engineering and Advanced Technology, Universiti Teknologi Malaysia, Jalan Yahya Petra, Kuala Lumpur, Malaysia

ARTICLE INFO

Article history:
Received 5 June 2018
Received in revised form 14 November 2018
Accepted 22 December 2018
Available online 29 December 2018

ABSTRACT

In today's very competitive business environment around the world, organizations need to be lean and mean as their strategy for competitive advantage. For the company under study, the management has decided to deploy Lean Six Sigma program as a structured methodology to improve the organizational performance since year 2016. The organization has chosen to embark on Lean Six Sigma journey in conducting its business process transformation as the means to improve its business efficiency and optimize its' operating cost. One of the business areas where Lean Six Sigma was deployed was to establish strategy to optimize and reduce inventory values to minimum by the end of the Power Purchase Agreement tenure. This study attempts to evaluate the effectiveness of the methodology deployed. The research is to explore in depth what is the characteristic of Lean Six Sigma methodologies when applied in this aspect. What are the factors those may influence the succes its implementation. The problems faced during the journey will be examined to identify the limitations of the Lean Six Sigma methodology may have and how it can be made better.

Keywords:
Lean, six sigma, lean six sigma, business process improvement, structured business process, transformation, strategic inventory management

1. Introduction

Since the beginning of industrial age, business from all sectors has been working hard towards maximizing quality to serve the world better while earning best profit possible. Technological advancement promotes demands and expectation from customers or voice of customer for flexibility. One of the areas is the management of spare parts inventory. From operational perspective, spare parts are kept in stock as inventory to minimize the risk of downtime due to equipment parts failure. However, from accounting perspective, spare parts inventories are non-liquid asset which depreciates over time. As such, depreciable assets should be kept at minimum or even eliminated. Many approaches deemed to have come close in improving

[*] *Corresponding author.*
E-mail address: syazli@utm.my (Noor Azam Md Saad)

inventory management in order to minimize the cost of holding spare parts inventory, thereby the amount saved from non-liquid assets can be utilized as working capital for the business.

The organization under studied decided to embark on Lean Six Sigma journey since 2016 as the strategy to improve the company's internal processes as to make it more competitive to face the ever challenging business environment. In the first phase of its implementation, one of the projects was Warehouse Inventory Value Optimization at one of its' power plants. Details of the projects and their outcomes are described later in this paper.

2. Literature Review

Lean Six Sigma is the combination of two different methodologies. "Lean" focuses on eliminating non-value added waste from a process in order to streamline production, improve quality and gain customer satisfaction in the long term. "Six Sigma" is a business management strategy that uses statistical methods to measure the capability of processes to determine the usefulness of the process in achieving customer's needs [1]. Lean Six Sigma is a synergized managerial concept of Lean and Six Sigma [2]. In short, Lean exposes sources of process variation and Six Sigma aims to reduce that variation enabling a virtuous cycle of iterative improvements towards the goal of continuous flow.

2.1 The fundamental of Lean and Six Sigma

Lean Six Sigma uses the DMAIC phases similar to that of Six Sigma. Lean Six Sigma projects comprise aspects of Lean's waste elimination and the Six Sigma focus on reducing defects, based on critical to quality characteristics [3]. Lean defined as systematic approach to identifying and eliminating non value add (wastes) through continuous improvement, flowing the product at the pull of the customer in pursuit of perfection [4]. Although several researchers have provided empirical evidences of the importance of lean on performance, some might have overlooked that the length of lean production adoption would be a catalyst in enhancing this linkage [5].

2.2 Lean Six Sigma in Non-Manufacturing Areas

Lean Six Sigma concept can be implemented to any kind of industries, for better performance, Lean Six Sigma is a continuous improvement tool for betterment [6]. Ainuddin Omar *et al.*, [7] suggested that there are still many non-manufacturing companies those have come to the conclusion that Six Sigma will not work for them. This is because Six Sigma was originally developed for helping the manufacturing industry. Of late, organizations such as health care systems, financial service providers and educational systems begin to realize the benefits of implementing Lean and Six Sigma in their organizations.

The impacts of these tools on project identification were studied, patient access, wait times, billing, and several other important facets of medical practice operations [8]. Biniam Gebre observed that Lean Management helps public sector organizations streamline processes by addressing the causes of organizational inefficiency, building the management systems and capabilities to sustain new ways of working, and engaging everyone in making continuous improvement a part of daily work [9].

There are many of the impacts reported and noted in organisations identified presented in terms of reduction of (processing or waiting) time, increase in quality through a reduction of errors or 'failure demand', reduction in costs (through less resource), increased employee motivation and satisfaction (particularly related to RIEs) and increased customer satisfaction [10].

2.3 Application of Lean Six Sigma in the Management of Inventories

By using Six Sigma Tools, the root source of inventory overstock will be revealed and according process can be improved, thus to achieve the goal of inventory optimizing and customer satisfactory elevating [11]. This results in eliminating excess stock or shortage wastes. For organizations those are self financed, they focused more on the search for new methodologies that allow them enhancing their financial results by decreasing the inventory costs and improving their process and customers satisfaction [12].

In healthcare, as in other industries, inventory is an expensive buffer that often covers up problems [13]. The Pharmacy Inventory Project also illustrates how to take a large and seemingly overly complex problem and break it down into more manageable components. The study by Kholopane [14] demonstrates how the application of Six Sigma can be done to reduce waste and save costs by identifying slow moving and redundant stock which can be extended into other sub products instead of them being scrapped, thus reducing stock write off and making the company competitive and productive. Lean inventory system in healthcare is the system that focuses on timely replenishment of items [15]. However, very few of its benefits have been empirically demonstrated and the extent of each of them remains unknown. A stock-out incident of a high critical items could threaten a patient's life [16].

Good material management is one of the key issues in ensuring that a project can be completed timely and safely [17]. As one of the project resources, material inventory is a point that needs to be managed very well. An application of Lean Sigma methodology is applied on to reduce surplus materials of project and maintenance. This indicates that, depending on what are the objectives of the application and problems that one is trying to solve, different tools are required but the initial approach will still be the same, which is the application of DMAIC tool [18]. Clear definition of problem statement, measured values and proper control implied ultimately secures situation firmly.

3. Inventory Value Optimization Project

In one of the operating units power plant, it was observed that the inventory value is building up from year to year at average about 9% per year. The management foresee that a strategic plan is required to ensure that the build up of inventory is kept well under control.

The power plant comprises of two operating plants owned by different subsidiaries. Since the two operating subsidiaries have their respective Power Purchase Agreement those expired at different times, a strategy is required to be formulated such that for one subsidiary, the inventory has to reach the minimum level by the year 2027 and for the other subsidiary, the inventory has to be at minimum by the year 2022.

3.1 Define Phase

The purpose of the define step was to establish clear goals and objectives of the project [1]. During the phase, a project charter was developed, which included problem and goal statements, the scope for the project and the customer deliverables [2,4]. While it is very important to focus on defining what the problem is and what will be delivered at the end of it from a customer's point of view, it is of equal importance to identify what items will be considered to be in scope for the project to avoid project overrun. The primary objective of this project is to establish strategy to reduce inventory values at the particular operating site to minimum by the end of the Power Purchase Agreement (PPA).

The Project Charter is the main governing document for the project and for this particular case, the Project Charter was approved by the Project Sponsor, which is the Head of Local Generation Assets Division of the company. Any subsequent changes to the contents of the Project Charter cannot be changed without the endorsement and approval by the Project Sponsor. The Project Charter is as shown in Figure 1.

The charter for this project set the goal of delivering provisional results within the required timeframe, while also improving the clarity and efficiency of the data collection process.

PROJECT CHARTER

Project Champion: HEAD OF DIVISION
Co-Sponsor: PLANT MANAGER

Project Leader (BB/GB) : Green Belt Leader

CURRENT SITUATION/BACKGROUND	**VOICE OF CUSTOMER/STAKEHOLDER ANALYSIS**	**PROJECT TITLE**
Inventory value is build up from year to year at average about 9% per year that causes high inventory value. Strategic plan required to ensure the build up of inventory in control.	**Voice Of Customer/Stakeholder (VOC)** Inventory Value Optimization **Stakeholder Needs** • Reduce inventory Value • Optimize spare parts usage & purchase **Stakeholder Specific Needs** Reduce Inventory value	**Inventory Value Optimization** To Establish strategy to reduce inventory value to minimum value by the end of PPA (Subsidiary A by 2027 & Subsidiary B by 2022)
PROJECT GOAL	**ESTIMATED COST SAVING**	**KEY ACTION (CURRENT)**
✓ To reduce Inventory Value by 20% ✓ To establish strategy by end of July'17	RM60mil (subject to outcome of Analysis & improve stage)	- Develop fish bone diagram - Develop data collection plan - Process mapping - Develop FMEA
BARRIERS TO SUCCESS	**PROCESS SCOPE**	**KEY TEAM MEMBER**
✓ Segregation of spares and consumables in the inventory list ✓ Identification of parts categories critical & Non critical ✓ To get commitment from the resources required within the team	**Start Process:** Spare parts Planning/reservation – Plant & HQ **End Process:** Material Out to End User **PROJECT SCOPING** **In Scope:** Subsidiary A & B Spare parts inventory **Out of Scope:** Consumable, Non-stock, Plant C & Plant D	1. Mohd Norazam Shah 2. Mohd Rafee(BPI) 3. Ezraila (Commercial) 4. Zaidi Zainol (HEM) 5. Mohd Sharizal (HOS) 6. Asrulnizam (Warehouse LPP) 7. Raziyah (Account) 8. Haslina (Planner LPP) 9. Sarihan (EA) 10. Engineering Team (LPP)

Fig. 1. The Project Charter

As part of this phase, a Gantt chart with specific deadlines as shown by Figure 2 was developed by which each phase of the DMAIC process would be completed. It was observed that when running process improvement projects it is necessary to keep a definite schedule for the project to be effective and avoid project fatigue.

Journal of Advanced Research in Business and Management Studies
Volume 13, Issue 1 (2018) 39-54

PROJECT TIMELINE

Phases	Project Plan	Start Date	End date	Jan	Feb	Mar				Apr	May	June	July	Aug
						W1	W2	W3	W4					
Define	Plan	11/1/17	17/1/17											
Measure	Plan	23/2/17	20/3/17											
Analyse	Plan	6/3/17	31/3/17											
Improve	Plan	3/4/17	28/4/17											
Control	Plan	1/5/17	31/5/17											

Measure Phase Activities Week 1 to Week 4:

1. Review Project Charter
2. Develop fish bone diagram, Develop data collection plan, Process mapping Develop FMEA
3. Coaching 1 & 2
4. Steering committee Tollgate
5. Collect & compilation of data (initial stage measure purposes)

Fig. 2. Project Timeline

3.2 Measure Phase

In measure phase, it was the identification and development of a number of metrics for the inventory management and control, to identify possible areas for improvement and evaluate their impact in the overall process [1]. In order to improve the clarity of the process it was critical to develop the Process Maps [4]. The first Process Map helped define and describe the "as is" process and would prove an essential tool in implementing process improvement. This is shown in Figure 3 below. Several process mapping workshops were held during which staff from the relevant sites were gathered and outlined the tasks they completed as part of the overall process. These tasks were detailed in the form of a flow chart and the actual mapping exercise resulted in all members of the project team having a greater appreciation and understanding of the overall process together with their own role in that process.

The process maps were then verified by the project team members through the use of a section walkthrough of the map to ensure all tasks had been captured correctly. In order to measure the time spent on the various processes we also used a Gantt chart to outline the major steps in the process, their start time and their duration.

Quantitative data were collected. The first set of data was the value of inventory in Ringgit Malaysia (RM) for the past 2 years, or 24 months. This is as shown by Figure 4 above.
From the data collected, it indicated the need to further study the contributing factors to the problem and further stream down to identify the most significant factors, also known as the Vital Few Factors (Xs) affecting the outcome (Y) of the project, i.e. factors those contributed significantly towards high inventory value and cost escalations.

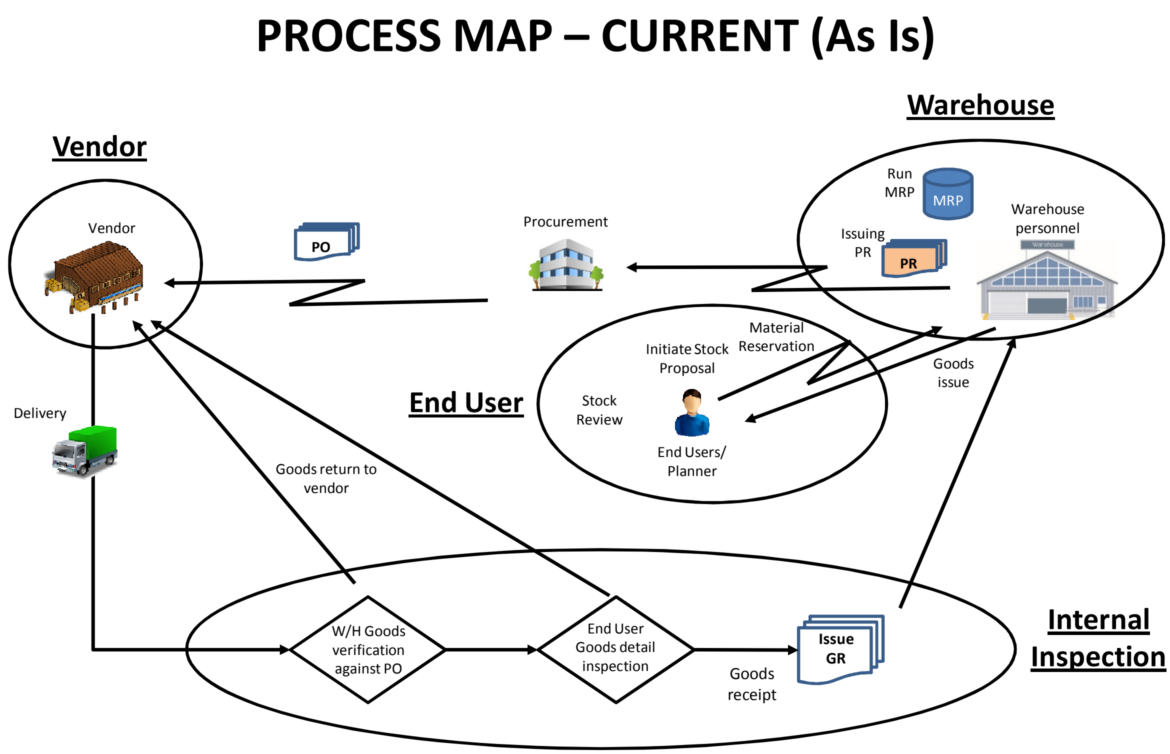

Fig. 3. Process Map (Current)

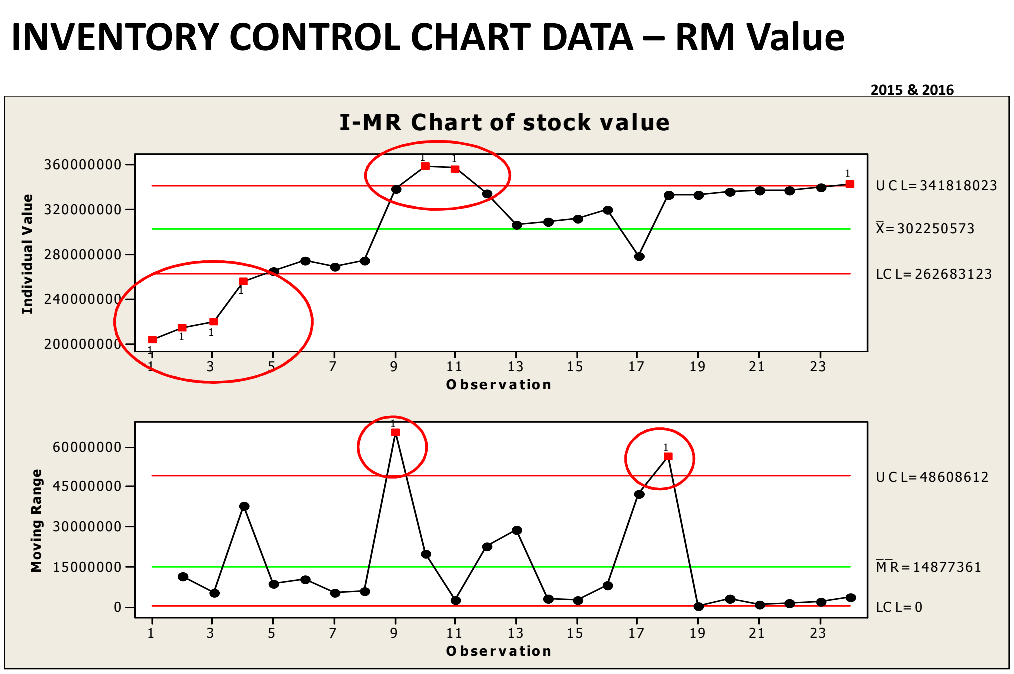

Fig. 4. Data of Inventory Value (RM)

3.3 Analyze Phase

The focus of the analysis step was to determine the factors those significantly contributing towards the problem [1,2]. The process is to identify all the factors thought to be causing the problem. For this exercise, brainstorming was conducted between the project team members and supported by the members from site. Fishbone Diagram was drawn and established. This is as described in Figure 5 below. The following step was to further challenge which factors were the most likely being more significant than others. The team members were requested to rank those factors listed in the Fishbone Diagram. From the ranking exercise, the team agreed that there were 9 factors out of 25 factors listed initially as described in the Fishbone Diagram. The 9 shortlisted factors are as depicted in Figure 6.

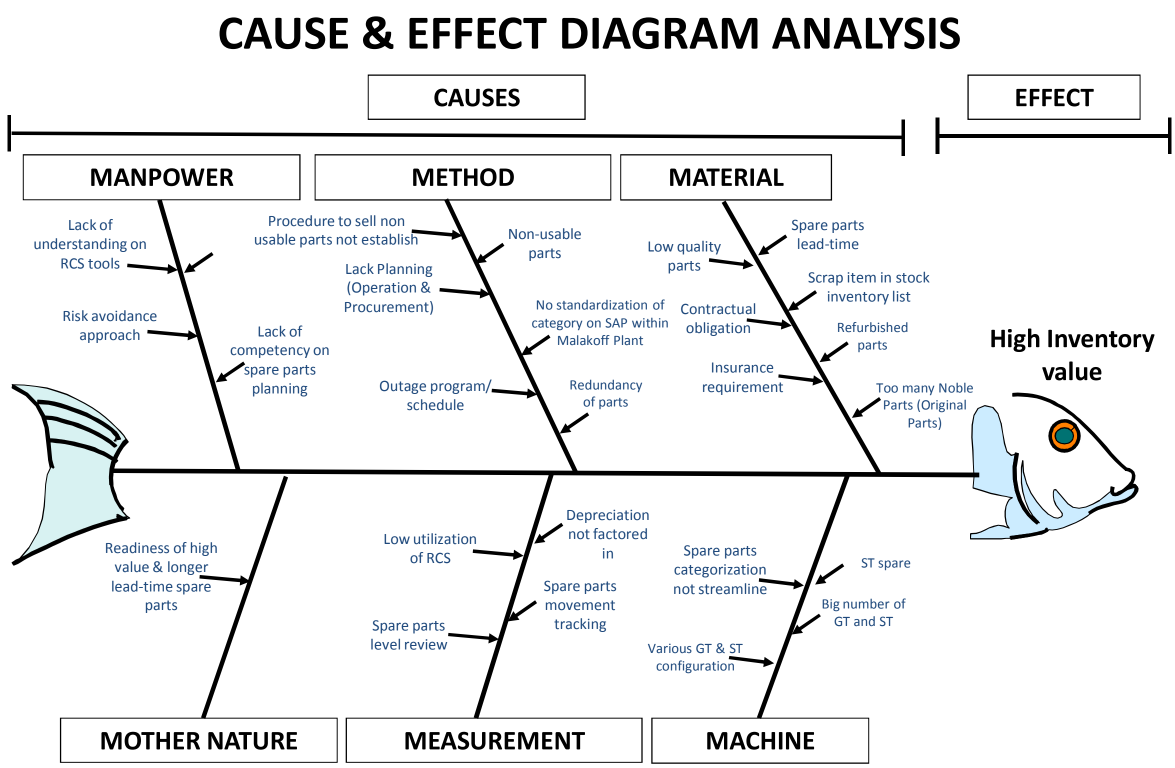

Fig. 5. Cause & Effect Diagram

In order to concentrate on the root causes or Vital Few Factors those significantly contributed towards high inventory value, the team conducted further analysis using recommended Lean Six Sigma Tools such as Regression Analysis as well as documentation evidence. The sample of analysis conducted are as shown in Figure 7 above.

From series of analysis conducted the Vital Few Factors are the outage program or schedule (X1), spare contractual obligation (X2), gas turbine spares (X3), long lead time for spares delivery (X6) and the present of redundant spares (X9) are the Vital Factors, while steam turbine spares (X4), refurbished spares (X5), low utilization of Reliability Centred Spares (RCS) Program (X7) and improper tracking of spares movement (X8) were not the Vital Factors.

SHORTLISTING OF VITAL FEW FACTORS (Xs)

$$Y_{(\text{High Inventory Value})} = f(X1 + X2 + X3 + X4 + X5 + X6 + X7)$$

X1	Outage program/ schedule
X2	Contractual obligation – OMA, OEM
X3	Gas Turbine Spares
X4	Steam Turbine Spares
X5	Refurbished Parts
X6	Spare Parts Long Lead-Time
X7	Low Utilization of RCS
X8	Improper spare parts tracking movement
X9	Redundancy of Spare Parts

$Y_{(\text{High Inventory Value})}$

Fig. 6. Shortlisting of Vital Few Factors

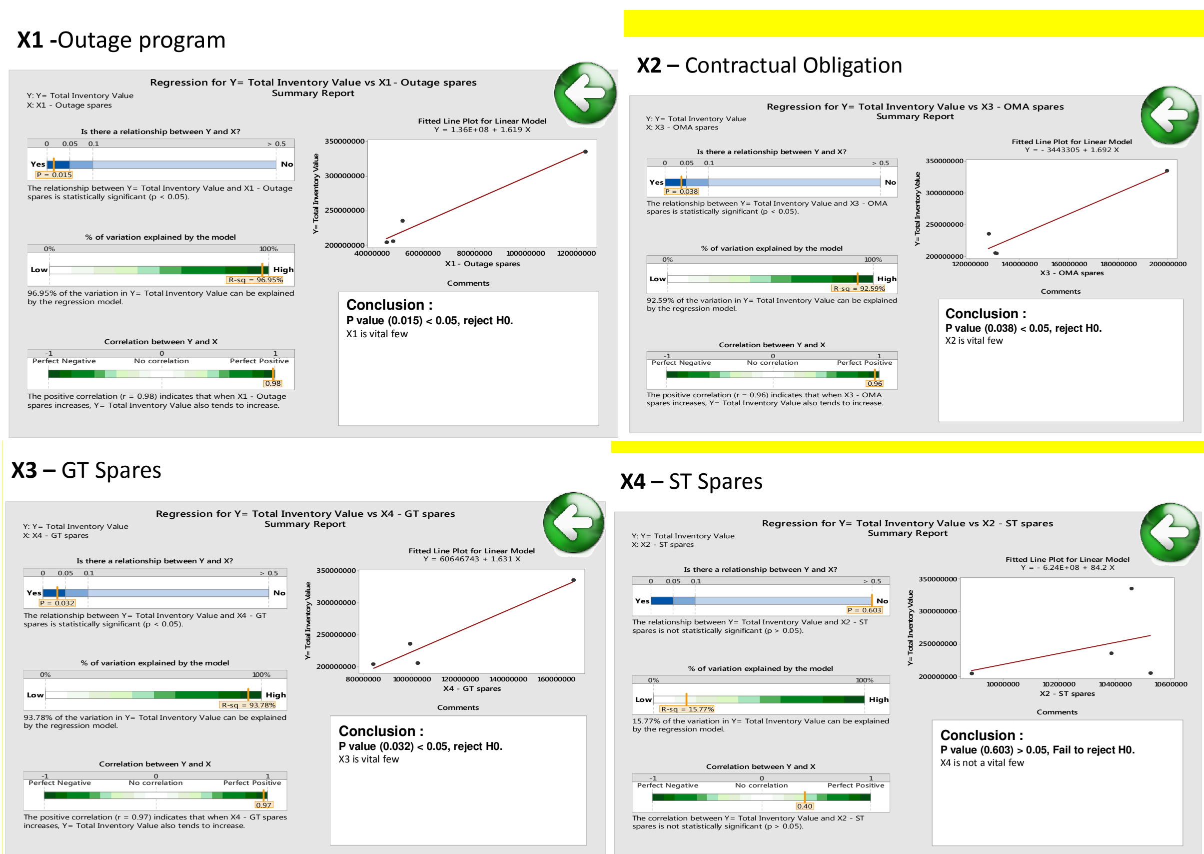

Fig. 7. Analysis to determine the Vital Factors

To deduce as whether the factors are vital or otherwise, Regression Analysis were used and the criteria was the P-Value. If P-Value is less than 0.05, the factor is considered as statistically significant. Otherwise, if the P-Value is more than 0.05, the factor is considered as not statistically significant [4]. The P-Value is the level of marginal significance within a statistical hypothesis test representing the probability of the occurrence of a given event. The P-Value is used as an alternative to rejection points to provide the smallest level of significance at which the null hypothesis would be rejected.

The summary of analysis to determine the Vital Factors and those Not Vital Factors are as described in Table 1.

Table 1
Summary of Vital Factors and Not Vital Factors

Potential Factors	Analysis Tools	Relationship Y & X P<0.05 is significant	Variation Model %	Correlation	Result
X1 - Outage Program/ Schedule	Regression Analysis	**P=0.015 Statistically significant**	R-sq = 96.95%	Positive correlation r=0.98 Y & X both tends to increase	**Vital Factor**
X2 - Contractual Obligation Spares	Regression Analysis	**P=0.038 Statistically significant**	R-sq = 92.59%	Positive correlation r=0.96 Y & X both tends to increase	**Vital Factor**
X3 – Gas Turbine Spares	Regression Analysis	**P=0.032 Statistically significant**	R-sq = 93.78%	Positive correlation r=0.97 Y & X both tends to increase	**Vital Factor**
X4 – Steam Turbine Spares	Regression Analysis	P=0.603 Statistically not significant	R-sq = 15.77%	r=0.4 Y & X both tends to increase	Not Vital Factor
X5 – Refurbished Spares	Regression Analysis	P=0.009 Statistically significant	R-sq = 96.99%	No correlation Y & X	Not Vital Factor
X6 – Long Lead-time Spares	Regression Analysis	**P=0.025 Statistically significant**	R-sq = 95.12%	Positive correlation r=0.98 Y & X both tends to increase	**Vital Factor**
X7 – Low utilization of Reliability Centered Spares (RCS) Program	Document Evidence	Not significant	-	Not Applicable	Not Vital Factor
X8 – Improper Tracking of Spares Movement	Document Evidence	Not significant	-	Not Applicable	Not Vital Factor
X9 – Redundancy Spares	Regression Analysis	**P=0.028 Statistically significant**	R-sq = 94.50%	Positive correlation r=0.97 Y & X both tends to increase	**Vital Factor**

3.4 Improve Phase

Following the Analyze Phase, the team deduced the following recommendations to improve the inventory management in accordance to the project goal as set out in the project charter [1]. In the Improve Phase, the proposed solutions or recommendations generated during Analyze Phase were further refined and the recommended actions were then prioritized.

X1 – Overall Outage Program or Outage Schedule Management

The recommendations were to optimize the major overhaul cycles, by optimizing the interval between the Major Inspection (also known as C-Inspection) of any units to coincide with timing of refurbishment the spareparts. Next is to optimize the running hours by negotiating the dispatch factor revision with the electricity off-taker. To perform intermediate inspection in order to gain 10% extra Equivalent Operating Hours (EOH) prior to the Major Inspection. This involves more critical outage planning and the final recommendation is to maximize the EOH of the operating Gas Turbine units before end of the Power Purchase Agreement (PPA).

X2 - Contractual obligations related to spareparts

For this factor, the team recommended to seek the management consent for waiver of certain clauses regarding inventory, including to resolve the issues on categorization of Initial Spares, Emergency Spares & Noble Parts (gas turbine main spareparts).

X3 – Gas Turbine Spareparts Management

The objective was to optimize usage of Gas Turbine spares towards the expiry of PPA, i.e. by end of years 2022 & 2028 respectively. The recommendations were to sell those disposable items, adopt just-in-time strategy (forecast C-inspection if required purchase or refurbishment) to ensure that the materials are delivered just-in-time before or during the inspection period.

X6 – Long delivery lead-time of the spareparts

For those long delivery lead-time of some spareparts, the recommendations were to synergize with other power plants for spare part sharing. Other recommendations are to collaborate with Original Equipment Manufacturer (OEM) for parts storage at their warehouse (preferably close to plants site) and to further strengthen the planning towards outage program.

X9 – Redundant or duplication of spareparts

For redundant spareparts, it was recommended that if parts are commonly used for both power plants, only one common material group number (Material Code) should be assigned. The objective was to maintain only one common number for all identical spareparts. The extra material resulted from the exercise, particularly those not required immediately shall be sold or auctioned.

The proposed solutions were then ranked and their priority in which there were to be implemented were prioritized. This is as shown in Figure 8. During prioritization stage, three criteria were chosen. For each of the criteria, they were given weightage (%). The decision for the criteria and their weightage were based on the standard guide set by the Lean Six Sigma Secretariat based on advise by the Lean Six Sigma Consultant and endorsed by the Lean Six Sigma Supreme Council set earlier.

The criteria were the Process Impact, or the degree of difficulty to implement the solutions (45%), Time Impact, i.e. the time required to implement the solutions (25%) and Cost to Benefit Impact (30%).

SOLUTIONS PRIOTIZATION MATRIX

Root Cause / Factor (X)	Proposed Solutions	Process Impact (45 %) 3 – High 2- Medium 1 - Low	Time Impact (25%) 3 – < 1month 2 – 1-3 months 1 - > 3months	Cost – Benefit Impact (30%) 2- Cost not incurred 1 – Cost incurred	Showstopper	Total	Priority
X1 - Outage spares	Optimize Major Overhaul Cycles	3 135	3 75	2 60	Increase in plant dispatch	270	2
	Perform intermediate inspection to gain 10% extra EOH prior C-inspection (Planning)	3 135	2 50	1 30	Mgmt. approval	215	10
	* Maximize EOH of GB3 units before end of PPA at 2022 (Planning)/(SEV similar approach)	3 135	2 25	2 60	Dispatch pattern (GSO)	245	4
X2 - Contract Obligation	Seek Mgmt. consent for waiver of certain clauses regarding inventory	3 135	2 50	2 60	No support from Mgmt.	245	5
	Resolve issues on categorization of Initial spares, Emergency spares & Noble spares	3 135	1 25	2 60	Contractual requirement	220	9
X3 – GT spares	Optimize usage of GT spares towards PPA by end of 2022 & 2028	3 135	3 75	3 90	Increase in plant dispatch	275	1
	Sell disposable item	1 45	1 25	2 60	Mgmt. approval & contractual requirement	130	13
	Adopt just in time strategy (forecast c-inspection if required purchase or refurbishment)	3 135	3 75	2 60	Risk taking/ Emergency requirement	270	3

SOLUTIONS PRIOTIZATION MATRIX (Cont'd)

Root Cause / Factor (X)	Proposed Solutions	Process Impact (45 %) 3 – High 2- Medium 1 - Low	Time Impact (25%) 3 – < 1month 2 – 1-3 months 1 - > 3months	Cost – Benefit Impact (30%) 2- Cost not incurred 1 – Cost incurred	Showstopper	Total	Priority
X6 - Long lead time spares	Synergies with other IPPs for spare part sharing	3 135	1 25	1 30	No support from other IPPs	190	11
	Collaborate with OEM for parts storage at their warehouse (close to plants)	3 135	1 25	1 30	No support from OEM	190	12
	Planning towards outage program	3 135	2 50	2 60	Dispatch pattern (GSO)	245	6
X9 - Redundant Spares	If parts are commonly used for SEV & GB3, assign 1 common material grp no.	2 90	3 75	2 60	GB3 PPA extended	225	7
	If parts are not common and cannot be shared between SEV & GB3, assign 1 material grp no. in each SEV & GB3.	2 90	3 75	2 60	GB3 PPA extended	225	8
	Sell do not required/extra (from initial handover) spares	1 45	1 25	2 60	Mgmt. approval & contractual requirement	130	14
	Maintain 1 common number for all duplicated spares	1 45	1 25	2 60	NA	130	15

Fig. 8. Solutions Prioritization Matrix

3.5 Control Phase

Control Phase is the stage whereby the recommended solutions were then put forward for implementation [1]. There were 15 number of solutions recommended to the implemented. The implementation of the recommended solutions were carried out based on the priority set during the Improve Phase. The recommended solutions were prioritized in the following order as shown in Table 2.

Table 2
List of recommended solutions and their priority

PRIORITY	RECOMMENDED SOLUTIONS	SHOW STOPPER	ROOT CAUSE FACTOR (Xs)
1	Optimize the usage of Gas Turbine spares towards the end of PPA by more detailed planning and coordination between the operation, maintenance, procurement as well as the Head Quarters teams.	Increased of plant dispatch beyond the initial plan. The dispatch pattern is not under full control of the power plant, but it is under the jurisdiction of the customer (off-taker)	X3 - Gas Turbine spareparts management
2	Optimize the Major Overhaul cycles by strategically plan the units outage with strong consideration on the utilization of spareparts.		X1 – Overall outage program or outage schedule management
3	Adopt just-in-time delivery of spareparts strategy such that the spareparts were to be delivered just-in-time before or during the scheduled inspection period.	Risk apatite – How much risk on spareparts stock-out can be tolerated during emergency situation	X3 - Gas Turbine spareparts management
4	Optimize the Equivalent Operating Hours (EOH) of the gas turbine units before end of the respective Power Purchase Agreement (PPA).	The dispatch pattern is not under full control of the power plant, but it is under the jurisdiction of the customer (off-taker)	X1 – Overall outage spareparts management
5	Seek management approval to waive / amend certain clauses present in the inter subsidiary agreement (Operation & Maintenance Agreement) related to the obligations to maintain the inventory level.	No getting the approval from management review the agreement.	X2 – Contractual obligations related to spareparts
6	More structured and detailed planning of the outage program with consideration on the strategic utilization of the spareparts (Similar to Item No. 2)	The dispatch pattern is not under full control of the power plant, but it is under the jurisdiction of the customer (off-taker)	X6 - Long delivery lead time of the spareparts
7	To review and assign only one material number (code) for identical spareparts.	Not agreed by the subsidiary's owner.	X9 - Redundant Spares (duplication)
8	If parts are not common and cannot be	If the Power Purchase	X9 - Redundant

PRIORITY	RECOMMENDED SOLUTIONS	SHOW STOPPER	ROOT CAUSE FACTOR (Xs)
	shared between the two subsidiaries, to assign only one material group number in each of the subsidiary.	Agreement for one of the subsidiary is extended, the plan will have to be reviewed.	Spareparts (duplication)
9	Resolve issues on categorization of Initial Spareparts, Emergency Spareparts & Noble Spareparts.	Not agreed by the respective management of the subsidiaries to review the agreement.	X2 – Contractual obligations related to spareparts
10	Perform intermediate inspection to gain 10% extra Equivalent Operating Hours (EOH) prior Major Inspection (C – Inspection).	Fail to obtain approval from the management.	X1 – Overall outage spareparts management
11	Collaborate with other power plants (other Independent Power Producers) for spare part pooling.	Fail to obtain support from other power plants.	X6 - Long delivery lead time of the spareparts
12	Collaborate with Original Equipment Manufacturer (OEM) for parts storage at their warehouse (to be delivered for usage as and when required within the acceptable timeframe).	Fail to get support from OEM	
13	To dispose or auction the extra / redundant spareparts.	Fail to obtain approval from the respective management of the subsidiaries.	X3 - Gas Turbine spareparts management
14	To dispose or auction the extra / redundant spareparts from the initial handover of spareparts.	Fail to obtain approval from the respective management. Fail to obtain consent from the related parties to review the contractual requirements or obligations.	X9 - Redundant Spareparts (duplication)
15	Maintain 1 common number for all duplicated spares (Similar ti Item 7).	Fail to obtain local plant management consent.	

From the above list of recommended solutions, some were solely under the purview of the power plant management and the organization. However, there are some recommendations those not under full control of the organization, i.e. require agreement and consent from external parties.

4. Observation and Discussion

With reference to the list of recommended solutions in Table 2, the recommendations can be divided into four categories as follows:

- Can be implemented solely by the plant personnel and under full jurisdiction of the organization.
- Require review or amendment to the existing inter-subsidiary agreement (Operation & Maintenance Agreement).
- Not under full control of the organization. The unit dispatch is under the instruction / request of the customer (off-taker) and so does the decision to review or extend the Power Purchase Agreement (PPA) beyond the current expiry dates.
- Require support and agreement of external parties such as other power plant operators or the Original Equipment Manufacturer (OEM).

Based on the above categories, only items number 5, 7, 9, 10, 13, 14 and 15 are under full jurisdiction of the organization or the subsidiaries involved. However, the entire strategy is still subjected to the main assumption of the respective Power Purchase Agreement will expire as per the stated dates and not to be reviewed or extended further. The decision to review or extend the Power Purchase Agreement is subjected to mutual agreement between the organization and the customer (off-taker). In this respect, the Lean Six Sigma exercise conducted has managed to bring about the underlying information regarding the situation.

However, despite of the list of recommendations or solutions identified, the real outcome or the results of the Lean Six Sigma exercise are subjected to parameters those not fully under the jurisdiction of the organization. The parameters those beyond the jurisdiction of the organization are the dispatch pattern in the day-to-day operation of the units and the actual expiry dates of the Power Purchase Agreements (PPAs).

During the course of conducting the projects and subsequent implementation of the approved recommended solutions, almost all teams reported that time constraints by the team members as one of the hurdles need to be overcome. In the case here, all team leaders and members are from respective sections and departments. All of the members have their own day to day operational task. Involvement in Lean Six Sigma is additional task to them. To overcome this, again it is important for the top management to link the success of Lean Six Sigma to a fair reward system to ensure sustainability of the program. Another common problems faced was the difficulty to obtain data in terms of quantity as well as quality. Lean Six Sigma is a methodology that relies on data. As such, the outcome of it depends a lot on the input data. For the organization that is the first time embarking on Lean Six Sigma Program, it is now recognized that it is very important to archive data in structured way for easier analysis later. During this pilot project, most of the data were extracted from the SAP system. These are the most reliable and accurate data. For those data not available or not stored in SAP, the quality and accuracy of these data can be questionable.

5. Current Status

Up to this date, a number of action items have been implemented. The actions taken were:

- Review of redundant (duplicated) spareparts to identify and assign only a single Material Number (Material Code) for identical spareparts.
- Identify surplus or extra material resulted from Item No. 1 above.
- Coordinate between Operation, Maintenance, Procurement as well as the Head Quarters teams in terms of strategic purchasing of spareparts following Items 1 and 2. This is an on-going process.
- Approval from the Board of Directors (management) has been obtained to amend certain clauses in the inter-subsidiary agreement (Operation & Maintenance Agreement). The clause whereby the operator needs to replenish all spareparts once consumed has been waived.
- Segregation of spareparts and consumables in the overall inventory list - On going.
- Identification of spareparts categories for critical and non-critical spareparts – On going.

The followings are the list of actions items are subjected to strategic decision to be made by the management:

- To dispose or auction the extra / redundant spareparts as identified in Item 2 above. This is also linked to the risk apatite of the organization, whereby the action could increase the risk of spareparts stockout during unscheduled shutdown or emergencies.
- The status of Power Purchase Agreement, either to propose to the customer (off-taker) be extended or otherwise.

Apart from the list of action items to be implemented, the team also recommended specifically who or which party to implement the action items. The feedback received were time constraints by the power plant people due to their existing day-to-day task. At this juncture, support and direction from the top management is seriously needed to emphasize the importance to carry out all the approved Lean Six Sigma recommended action items within the stipulated timeline.

6. Conclusion

From the study conducted and based on experience gained during the deployment of Lean Six Sigma in the organization, it can be concluded that Six Sigma is indeed a business strategy that can provide a breakthrough improvement in the competitive era. However, there were also factors or elements those were not under full jurisdiction of the organization. These external factors unfortunately can bring about significant impact the actual outcome or the results of the Lean Six Sigma project. Factors such as the dispatch pattern of the operating units which governs the Equivalent Operating Hours (EOH) of the units which then affecting the usage of the spareparts were not under full control and jurisdiction of the organization. The decision to review or extend the Power Purchase Agreement is subjected to mutual agreement between the organization and the customer (off-taker).

Another challenge faced was the difficulty to obtain data in terms of quantity as well as quality. For the organization that is the first time embarking on Lean Six Sigma Program, it is very important to recognize the need to archive data in structured way for easier retrieving and analysis later. Finally, Lean Six Sigma demands time commitment the team leaders, team members as well as the project sponsors and the top management itself. All team leaders, team members as well as the sponsors have their existing day-to-day operational task. Involvement in Lean Six Sigma is an additional task. At this juncture, support and direction from the top management is seriously needed to emphasize the importance to carry out all the approved action items within the stipulated timeline. It is also recommended for the top management to link the success of Lean Six Sigma program to a fair reward system to ensure sustainability of the program.

References

[1] Susana Portillo. "Using Lean Six Sigma in Business Surveys; Practical Example." 2016.
[2] Bevan, Helen. *Lean Six Sigma: some basic concepts*. NHS Institute for Innovation and Improvement, 2006.
[3] Kumar, Sanjay, Sunil Luthra, D. Garg, and A. Haleem. "Lean six sigma implementation: An analytic hierarchy process approach." In *NITIE-POMS Conference*, pp. 18-21. 2014.
[4] Ahmed Mousa. "Lean, Six Sigma and Lean Six Sigma Overview." 2013.
[5] Agus, Arawati, and Rosman Iteng. "Lean production and business performance: The moderating effect of the length of lean adoption." *Journal of Economics, Business and Management* 1, no. 4 (2013): 324-328.
[6] Muthukumaran, G., V. S. K. Venkatachalapathy, and K. Pajaniradja. "Impact on integration of Lean Manufacturing and Six Sigma in various applications-a review." *Journal of Mechanical and Civil Engineering* 6, no. 1 (2013): 98-101.
[7] Ainudin Omar & Zainol Mustafa. "Implementation of Six Sigma in Service Industry." 2014.
[8] Doug Penner. "Lean Six Sigma for Medical Practices: Opportunities for Performance Improvement." 2013.
[9] Kathy Lindquist. "Synthesis of Lean Information & Practice in Government." 2013.
[10] Radnor, Zoe J. *Review of business process improvement methodologies in public services*. Aim Research, 2010.
[11] Biao Hu & Yun Tian. "Six Sigma applied in inventory management." 2011.
[12] Benmamoun, Zoubida, Hanaa Hachimi, and Aouatif Amine. "Inventory management optimization using lean six-sigma."
[13] The Academy for Excellence in Healthcare "Pharmacy Inventory Project: Improving Inventory Management at Genesis HealthCare System Pharmacies." 2014
[14] Kholopane, P. "The Effect of the Implementation of Six Sigma in Reducing Obsolete Stock and Controlling Stock Inventory at a Flavor Manufacturing Company: A Case Study." In *International MultiConference of Engineers and Computer Scientists*. 2016.
[15] Marasli, Hikmet, Rabia Sultan Halis, and Muhammed Furkan Halis. "Lean Medical Inventory Management in Hospitals." (2017).
[16] Al-Qatawneh, Lina, Abdallah Abdallah, and Salam Zalloum. "Reducing stock-out incidents at a hospital using Six Sigma." *World Academy of Science, Engineering and Technology* 7, no. 5 (2013): 404-411.
[17] Sotarduga Manurung. "Improvement material inventory tracking for maintenance and project through Lean Six Sigma methodology." 2011.
[18] Choong Kei Shing, Santhirasegaran Nadarajan & Sitraselvi Chandren. "Scraps Management with Lean Six Sigma." 2014.