LEAN IMPROVEMENT TO REDUCE USAGE RATE OF PRODUCTION SUPPLIES

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Declaration

I hereby declare that the Final Year Project entitled "**Lean Improvement to Reduce Usage Rate of Production Supplies**" submitted by me to Universiti Sains Malaysia; is a record of an original work done by me under the supervision of Dr. Chin Jeng Feng, senior lecturer of School of Mechanical Engineering at Universiti Sains Malaysia. This paper is submitted in the partial fulfillment of the requirements for the award of the degree of Manufacturing Engineering with Management. I further declare that this report has not been submitted and will not be submitted, either in part or in full, for the award of any other degree or diploma in this institute or any other institute or university.

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Date :

Acknowledgement

Throughout the journey of this case study, it has been a period of intense learning for me, not only in the scientific field, but also on a personal level. I would first like to thank my Final Year Project supervisor, Dr. Chin Jeng Feng, lecturer of the School of Mechanical Engineering at Universiti Sains Malaysia. The door to Dr. Chin office was always a welcoming sign whenever I bumped into a trouble, be it on writing this paper or carrying out the actual case study. His patience, motivation, enthusiasm, and immense knowledge steered me in the right direction and helped me in all the time of the research. I could not have imagined having a better supervisor for my Final Year Project.

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Abbreviations

ABC	Extremely Important, Moderately Important, Relatively Unimportant
AWG	American Wire Gauge
BOM	Bill of Material
BPU	Black Polyurethane
BSM	Bose System Malaysia
CRR	Coil Retainer Revolver
DMAIC	Define, Measure, Analyze, Improve, Control
FSN	Fast-moving, Slow-moving, Non-moving
HRM	Human Resource Management
IDEAL	Initiating, Diagnosing, Establishing, Acting, Learning
JIT	Just in Time
LM	Lean Manufacturing
MRO	Maintenance, Repair and Operating
PDCA	Plan, Do, Check, Act
ROHS	Restriction of Hazardous Substances
SAP	Systems, Applications, Products
SMART	Specific, Measurable, Achievable, Relevant, Time Bound
SOP	Standard Operating Procedures
TPM	Total Productive Maintenance
TQM	Total Quality Management
VED	Vital, Essential, Desirable
WIP	Work in Progress
8D	Eight Disciplines
5S	Sort, Set in Order, Shine, Standardize, Sustain

Abstrak (Bahasa Malaysia)

Rang undang-undang bahan (BOM) adalah senarai bahan yang biasa digunakan untuk memaparkan bahan-bahan yang diperlukan dalam process produk pembuatan. Bekalan pengeluaran, yang dikenalikan sebagai bekalan pengeluaran secara tidak langsung merupakan bekalan yang dikehendaki dalam proses pembuatan tetapi ia tidak disenaraikan dalam rang undang-undang bahan. Ciri-ciri sistem pengeluaran adalah berbeza antara satu sama lain, dan ia dibahagikan kepada beberapa varasi seperti tatacara penguatkuasa terhadap bekalan dan juga kuantitinya. Kesusasteraan menyatakan bahawa pemahaman yang kurang terhadap pengurusan bekalan pengeluaran secara tidak langsung akan menyebabkan industri hari ini mengalami kerugian dalam perniagaan dan ini boleh dikaitkan dengan kelemahan dalam pengurusan inventori, varasi lokasi menyimpan stok, kelemahan dalam perancangan pembelian bekalan pengeluaran dan kekurangan perhatian daripada golongan pengurusan dalam organisasi (Scheuing & Krauter, 2005). Tatacara ini bertujuan untuk mengurangkan pengunaan bekalan pengeluaran secara tidak langsung dalam sel Quantum melalui Kaizen. Metodologi "Plan-Do-Check-Act" (PDCA) fokus pada bekalan pengeluaran secara tidak langsung yang mempunyai kadar penggunaan yang tinggi. Pengurangan pembaziran dapat dicapaikan dengan mengunakan teknik-teknik kejat yang akan dibincangkan dalam manuskrip ini. Teknik-teknik kejat ini akan digunakan dalam empat tahap PDCA untuk memberi hala tujuan yang jelas dalam membuat keputusan. Tindakan yang diambil dengan rujukan kepada teknik-teknik kejat ini telah dibukti berkesan untuk mengurangkan pengunaan bekalan pengeluaran secara tidak langsung seperti yang dirancangkan. Pengunaan bekalan pengeluaran secara tidak langsung telah dikurangkan sebanyak 56.31%. Beberapa isu yang dibincangkan dalam manuskrip ini boleh dijadikan sebagai rujukan dalam kajian pengurusan operasi.

Kata kunci: PDCA, pengurangan bekalan pengeluaran secara tidak langsung, Kaizen dan teknik-teknik kejat.

Abstract

Production supplies are consumables used in production but have no direct connection to the product Bill of Material (BOM). A production requires varying quantities of heterogeneous production supplies and often independent regulating methods. Contemporary literature reveals production supplies management in industries often suffers from poor inventory records, multiple storage locations, uncoordinated purchasing, frequent out of stock conditions, and lack of managerial attention (Scheuing & Krauter, 2005). The manuscript presented a case study to reduce usage rate of production supplies in Quantum cell through Kaizen. The Kaizen followed Plan-Do-Check-Act (PDCA) methodology with focus prioritization on highly consumed production supplies. Lean tools were presented at different phases of PDCA to guide the group in decision making and implementation. Countermeasures were fully implemented and the usage rate was reduced as planned. The overall production supplies usage rate has reduced by 56.31% and the target has been achieved through those countermeasures. This case study offers a valuable reference and benchmark for Lean practitioners on similar usage rate reduction endeavors. Several issues highlighted could be worthwhile for operation management research.

Keywords: PDCA, production supplies reduction, Kaizen and Lean tools.

1. Introduction

Production supplies, often known as consumables or maintenance, repair and operating (MRO) supplies, are resources used in a manufacture's production process that are hard to be traced or precisely associated to the products or batches of products they produce (Roberto, Aurélio, & Mesquita, 2011). These items do not appear in the Bill of Material (BOM). They add little apparent value to the final product but are required for production (Roberto et al., 2011). These materials are usually small, inexpensive, and bought in mass quantities.

Production supplies management is a complex problem and part categorization is required to create a manageable control group to focus management effort more effectively (Prakash & Ganeshb, 1994). Hence, multi-criteria classifications are used, and there are several examples of classification schemes available in the literature. The complexity increases even more when the number of parts managed increases (Småros, 2009), the presence of intermittent or lumpy product demand pattern (Bacchetti & Saccani, 2012) and the risk of stock obsolescence (Vaisakh, Dileeplal & Unni, 2013).

Inventory management for production supplies is challenging compared to managing direct material due to inherent large item varieties as well as comparatively low and stochastic demand. Slow-moving parts have even irregular demand. In consequence, coupled with limited historical data, lead times of their requirements are largely unpredictable (Grondys, 2013). The value of production supplies purchase can be high compared to direct material (Wagner & Eisingerich, 2012). Implications of insufficient production supplies are over cost, production delay (Bailey & Helms, 2007), negative influence to product quality (Roberto et al., 2011). These occurrences will worsen client's perception.

Kennedy, Patterson & Fredendall (2002) have a definite view on production supplies: production supplies inventory differs from other manufacturing inventory in several ways. First, the function is different compared to direct material. Production supplies inventory aims to smooth out irregularities in production flow, while finished product inventory exists to provide a source of products for customer. These variations may result from changes in product mix, differences in production rates between different processes, material handling, equipment failures and many other things. Second, the policies to control production supplies are different from final product inventory. Size of production supplies inventory level is highly dependent on function of how equipment is used and maintained regardless the production schedule.

The mainstream research revolves around direct material control. A case in point is Arnold et al. (2008), a rather comprehensive handbook for material control with very limited reference drew to production supplies. The coverage of production supplies management or reduction is found scarce and sporadic in academic or industrial literature. Industrialists frequently treat production supplies as ‘necessary evil’ and hence neglect large opportunities to save money and improve performance (Scheuing & Krauter, 2005).

This case study aimed to reduce the usage rate of production supplies in a production. A problem-solving methodology based on Plan-Do-Check-Act (PDCA) was applied in this case study. The organization of this paper is as follows: Section 2 introduces the challenge of production supplies management and general tools proposed to manage and monitor production supplies. Section 3 presents PDCA methodology followed in the case study. Section 4 presents the company background in the case study. Section 5 explains the Plan phase, followed by the Do phase in section 6, Check phase in section 7 and Act phase in section 8. Section 9 presents the discussion of the case study. Finally, this paper is ended with conclusion in section 10.

2. Literature Review

Literatures relate to the management of production supplies: inventory control, usage prediction, supply issue, regulation. Arts (2013) derived a framework for maintenance production supplies planning and control which constitutes of various functions includes assortment management, demand forecasting, parts return forecasting, supply management, repair shop control, inventory control, order handling and deployment. Some uncommon functions are explained. Assortment management concerns the inclusion or exclusion of a production supplies in the stock control list. Part returns forecasting is made to determine the scrap rate based on multiple failure modes of the repairable parts.

Inventory control aims to ensure a company has an adequate supply of products all the times and avoid stock out. The variety of research in the management of production supplies inventory is very broad in scope. The literature includes non-technical treatment and more technical that offer a systemic view of production supplies inventory management. Grondys (2013) in an example of the less technical papers proposed an approach to manage production supplies based on reliability, capacity objectives and a systematic strategy. He suggested starting with a functional categorization of parts and the establishing of a thorough set of rules for each part category. Some indicators such as machine failure, part use history, lead times and supplier reliability need to be considered. On the other hand, more technical research is required to design models in order to improve existing system. Foote (1995) performed a case study at the aviation supply office regarding the implementation of a new forecasting system which focused on philosophy, mathematical principles and system design features. He concluded that sound statistical measurement and the application of statistical control techniques lead to significant improvement in inventory.

Prakash & Ganeshb (1994) attained to projected needs for production supplies before searching for optimal solutions. Similar to Grondys (2013), their proposed idea is to categorize the parts using variety of partitioning technique. The classification of production supplies is useful to prioritize effort and to define the inventory management system to handle them in better way (Wagner & Eisingerich, 2012). Several common classification methods for production supplies are presented next. ABC classifies items into three groups based on Pareto

Principle and monetary value of the consumption (Robson, Trimble & Macintyre, 2013). Pareto gives emphasis to the vital few compared to trivial many. VED analysis classifies items into three categories: vital, essential and desirable based on their criticality. Vital materials are those materials that are critically needed which must be available in production line all the times. If essential materials are not available beyond few days or a week, the production would be adversely affected. However, the shortage of desirable items will not adversely affect the production line even they are absence. A combination of ABC and VED had been applied by one of the hospitals in order to create an efficient inventory system policies to meet emergency demand conditions (Malhotra, 2015). FSN analysis categories them into three categories as Fast-moving, Slow-moving and Non-moving (Mitra, Prince & Scholar, 2015). Different categories of production supplies will have different inventory policies. Turnover ratio of each item is the most critical parameter that is required while performing this analysis. A case study had been conducted by using FSN-VED analysis to help production manager in managing production supplies better and to reduce inventory holding cost (Vaisakh et al., 2013).

Other classification is more straightforward and based on distinguishable aspect of the production supplies. Roberta & Taylor Bernard (2011) distinguished three categories of production supplies based on demand planning: maintenance parts which require regular storage, capital production supplies which are at medium level of reliability and generate higher purchase cost than parts of low reliability and reusable production supplies which include items that can be repaired and re-installed after being damaged. Priority and leverage made on managing the production supplies can be easily identified and executed by further breaking down them into these three categories. Demeter (2011) classified production supplies inventory based on their availability in the market and the volume of purchase: key parts, which are delivered by few suppliers and made against order, industrial parts which have low risk of lack of parts and relatively larger number of suppliers and commercial parts which have universal character and wide industry application. Arts (2013) grouped spare parts into either repairable, non-repairable (consumable) and ratable (one already prescribed with own maintenance program).

To monitor the production supplies inventory level, numerous methods have been proposed in literature. Almerico, Baker, & Matassini (2004) observed that the problem of determining stock quantities is made worse due to lack of current inventory level information. They recommended a method to obtain all the current information of inventory in real time. They provided a database management system on which to store and manage data of inventory and allow to eliminate uncertainty of stock in production line. Gerhard (2011) pointed out that system such as commercial software SAP system could deal with the problem of finding current inventory situation. SAP allowed them to access and monitor inventory by providing the level of parts, orders time, low level parts and much other statistic information (Al-bawi, 2002). Scheuing & Krauter (2005) dealt largely with the procurement and inventory control of indirect material. Strategies recommended including consolidation of multiple and rogue inventories, streamlined procurement and storing, improved control and transparency, standardizing parts etc.

Inventory management practice is to maintain production supplies store at a certain level to ensure smooth production flow and protection from unexpected events, while reducing uncertainty with quality issues and deliveries (Ali, 1995). One of the simplest maintenance policies is to replace items at the end of a pre-determined interval. General discussions on maintenance inventory had been presented by Seidel (1983). He gave a method for calculating the optimum reorder point and reorder quantities for inventory. He suggested using a reorder point equal to the lead time demand. This method has the advantage of being easy to understand, but it does not consider either fluctuating demand rates or the problem of getting good value for the ordering cost. Jose L. Gonzalez & Daniel Gonzalez (2010) explained that the effectiveness past usage of production supplies is normally used to set their reorder points and reorder quantities. These values, sometimes called minimums and maximums which are used to drive the procurement of production supplies.

Sarantis (2002) derived a step-by-step guide for reducing paper consumption primarily for service industries, which included setting vision, initial assessement of inefficient paper use, buy-in (support) from top leadership, team organization, paper consumption audit, prioritization of paper reduction efforts, pilot project, encouraged involvement, vendor education and results tracking.

While Lean manufacturing (LM) has been demonstrated to aid companies to improve operations, notably on quality, delivery and cost, the connection of the concept for managing production supplies, in particular on the front of usage rate reduction is peculiarly faint. Next several potential related concepts and tools are elaborated. According to Christer & Par (1996), LM permeates an entire organization. The proper utilization of LM affects the whole firm. LM is not only a set of practices linked to the value-creation process, LM is also comprise the pursuit of excellence based on continuous improvement and organizational change (De Toni & Tonchia, 2014). Karlsson & Ahlstrom (2014) explained the following building block of LM: elimination of waste, continuous improvement, multifunctional teams, zero defects/ JIT, vertical information systems, decentralized responsibilities and pull versus push. There are numerous practices that can be implemented under LM. Ward (2002) listed four main Lean practices: just in time (JIT), total quality management (TQM), total productive maintenance (TPM) and human resource management (HRM). TQM, JIT and TPM have similar fundamental target: continuous improvement and waste reduction. One of the fundamental goals of LM is to eliminate excess inventories since they are considered as waste.

To reduce the production supplies inventory, several methods have been recommended in literature. The prevalent one includes the Plan-Do-Check-Act (PDCA) cycle, DMAIC, Initiating-Diagnosing-Establishing-Acting-Learning (IDEAL), 8D, etc. PDCA and DMAIC have the similar feature, but PDCA emphasizes more the need to repeat the steps, while DMAIC adds extra Control step lacking in PDCA. The fundamental principle of PDCA is iteration. Repeating PDCA cycle can lead us nearer to perfect operation (Chandrakanth, 2002). Despite of this iteration, it provides value in optimizing repeatable processes by way of reducing waste and making incremental improvement toward goal. In addition, PDCA introduces a pragmatic approach, which can establish continuous monitoring and improvement of inventory (Erlandsson & Duhan, 2008). Generally, PDCA uses fact, data, experiment and management tools to improve the process in a sequential way. However, the team might not able to get it perfect at the first PDCA cycle. With the improved knowledge of each PDCA cycle, the objectives of project will be met (Chandrakanth, 2011.). The versatility of PDCA framework is epitomized in different cases; improvement include problem solving and decision making (Naganathan, 2013), inventory management (Erlandsson & Duhan, 2008) and improving quality management (Wan & Zeng, 2013).

Good inventory management has high inventory turnover and minimum overall cost in inventory management (Meghna, 1984). JIT is a method that will only issue exact required quantity of inventory to production floor when it is needed. Fontaine (2011) suggested an approach to manage inventory based on JIT principles. Kanban is a signal to replace what has been used which could be used to control inventory. He concluded that it is a powerful tool for reducing waste during production since it is a direct communication to produce material.

Eliminating waste in production line is the highest priority of LM approach. Waste is an extra expenses of resources rather than creating value for the customers (Liker & Morgan, 2006). The common wastes in production line are excess inventories, unnecessary steps and scrap (Kuo, Shen & Chen, 2008). Reduction of wastes normally refers to the improvement of operational performance by increasing process consistency and streamlining processes (Zokaei

& Simons, 2006). Reduce waste allows the reduction of production supplies required while maintaining or even increasing the productivity of production. Hence, waste reduction will be acted as fundamental concept behind the study.

3. Research Methodology

The research is classified as action research. Action research, as defined by Reason (2006), is a democratic process to develop practical knowing in the pursuit of worthwhile human purposes. It brings together action and reflection, theory and practice and in participation with others. Carrying out action research develops the level of understanding and confidence through observation, listening, analyzing and questioning. Hargreaves (2002) pointed out that doing action research facilitates evaluation and reflection to implement improvement in practice and assists practitioners to study aspects of practice. The main author stationed at the case study company over the period of ten weeks to handle the project throughout, with the assistance of team members. Field mentor was provided to keep the project on track. The execution of every phase was observed and important data was collected faithfully. Discussion presents insights gathered by the main author as she has a direct exposure to the project, a significant aspect of action research.

The methodology used in this case study is broken into four phases, Plan-Do-Check-Act where each phase consists of number of stages (Figure 1). Those wastes in Quantum cell can be reduced by the help of PDCA (Plan-Do-Check-Act) cycle. Start from 1950s, Dr W. Edwards Deming created PDCA cycle (Chakraborty, 2016). In PDCA, the actual results of an action are compared with a target. The difference of them will be highlighted and some corrective measures are implemented. The main theory of PDCA is about continuous improvement which is always following the repeated and continuous nature cycle (Sokovic, 2010).

3.1 Plan phase

There are five distinct stages in Plan phase beginning from a clear definition of the problem statement, grasp current condition, define target condition, conduct root cause & gap analysis and summing up by identifying potential countermeasures. Through goal setting, the team can understand clearly on what they are working on. The goal is established with SMART – specific, measurable, achievable, relevant and time bound. Goal acquires the team to be specific with the statements and includes with measurable elements. It should not be too narrow nor to wide as to waste the team's capability and time bound. The current condition of the production operations must be well grasped. Data collection can provide solid evident for the current situation and help the team to comprehend what is the problem they are dealing right now and what steps they should take now. Number of useful Lean tools can facilitate team to overcome the related cause. Identifying potential countermeasures toward the root causes will be the last stage of this phase.

3.2 Do phase

Countermeasures identified in the previous phase will be conducted in the Do phase. Test and refining processes are crucial in determining the suitability and reliability of the improvements. Those improvements will be finalized and implemented once results are satisfied.

3.3 Check phase

Through this phase, in order to measure process performance, the actual outcomes will be compared to the desired outcomes. Goal that has been established in Plan phase will be set as baseline for reference.

3.4 Act phase

In the Act phase, controlling strategies are important for continuous improvements toward those implemented countermeasures. This phase involves the documentation of the entire improvement process so that the best practices can be standardized and stabilized. Common improvements are transferred and shared between departments within the organizations. Share learning will help the organizations to operate more effectively.

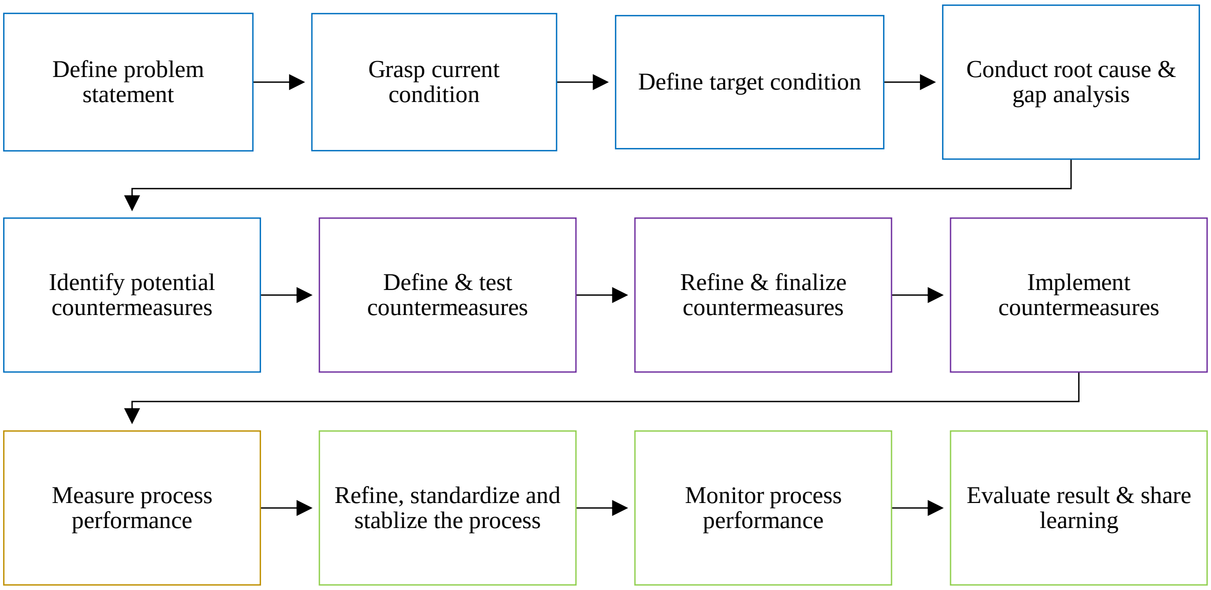

Figure 1 The 12 stages involved in PDCA cycle

4. Company Background

Bose System Malaysia Sdn. Bhd. was established in Malaysia in mid-2013 at Penang industry park at Batu Kawan to produce speakers, noise cancelling headphones, professional audio systems and automobile sound systems. Current workforce includes 2000 employees. The company has a long history practicing Lean six sigma and employees are required to go to relevant structured training program.

5. Plan Phase

5.1 Define problem statement and grasp current condition

The tenet of current project was to investigate and reduce the high usage rate of production supplies in Quantum cell, which is producing transducer. A range of information was collected in Quantum cell, which included the cost of production supplies, types of production supplies and demand of parts.

The usage rate of the production supplies was perceived high by the management and motivated this project. It was brought to lime light due to several reasons. First, the price of production supplies has increased significantly in the past few years. Second, the manufacturing cost of transducer has escalated somewhat proportionally to the usage rate of production supplies. Third, the pressure from business competition compelled the company to save cost aggressively.

The material issuing process flow was shown in Figure 2. Whenever the production supplies run out-of-stock in plant floor, the Quantum cell leader will raise an indent through integrated computer system. A production supplies request form where quantity is being specified will be send to Tool Crib via computer system. The Tool Crib hands over the requested production supplies to Quantum cell. A routine task has been assigned to the Quantum cell leader to ensure that the quantity issued from the tool crib is sufficient and meets the consumption of the line. The intention of enforcing such practice is to make sure that no excessive materials flows through the line and to reduce the material movement between the tool crib and production shop floor. Data entry via computer system enables the supplier (Tool crib personnel) and end user (production operators) to keep a well-defined record of the material issuance information such as date of transaction, quantity of issuance, type material issued, end-user information and delivery order information etc.

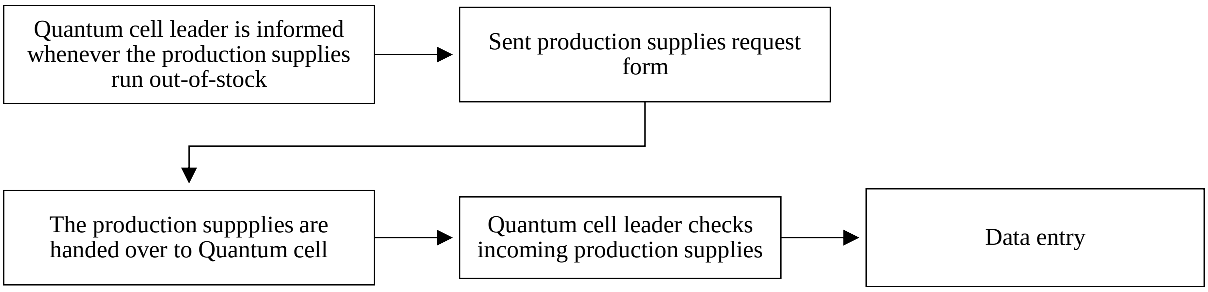

Figure 2 Material issuing process flow

To grasp the current condition, monthly production supplies cost of Quantum cell was traced. The tracing concentrated from Jan’16 till May’16. There are 88 production supplies in Quantum cell. There is a need to further confine the scope of tracing to production supplies with the most significant usage in term of cost. From the data given, highest 20% of the production supplies which had contributed roughly 80% of monthly production supplies cost were determined as shown in Figure 3. These items included coil retainer revolver (CRR), BPU glove, replacement tip, wire wrap sleeve, wrap bit, 22 AWG, resolver, 22GP .016 x .5 blue, tip, 1.6D, 900M, touch n tuff glove (S) and touch n tuff glove (M). They consumed roughly RM16K out of monthly production supplies cost of RM20K. Amongst them, cost of CRR was the highest with figure up to nearly RM5K. CRR is made from aluminium, a heat conductor material and is assembled to the voice coil which allows heat to be transferred from heating oven to the semi-assembled unit. This shortens the time needed to dry up adhesive material on the voice coil, and consequently reduces the manufacturing lead time of the transducer.

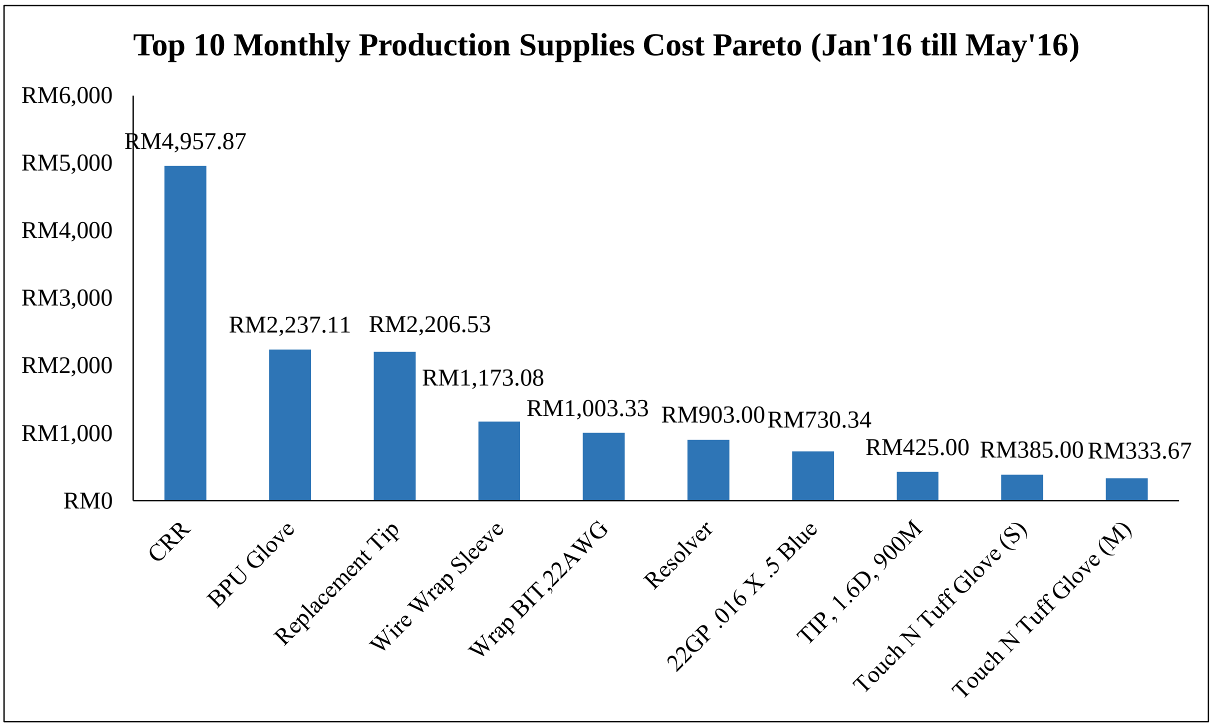

Figure 3 20% of production supplies that contributed 80% of monthly production supplies cost from Jan'16 till May'16

5.2 Define target condition

Material consumption normally varies according to the product demand from the market. To weigh in this relationship, the usage rate, which is the cost of production supplies over the corresponding transducer demand was adopted as alternative measure to the production supplies cost as shown in Figure 4.

Goal set a clear and defined path for the team to get all the necessities done to achieve the final objective. In this project, goal was defined to reduce production supplies usage rate from 0.103 to 0.052 (50%) by the end of Aug. Several obstacles were anticipated, such as multiple and potentially complicated root causes, investment and the allocation of resources.

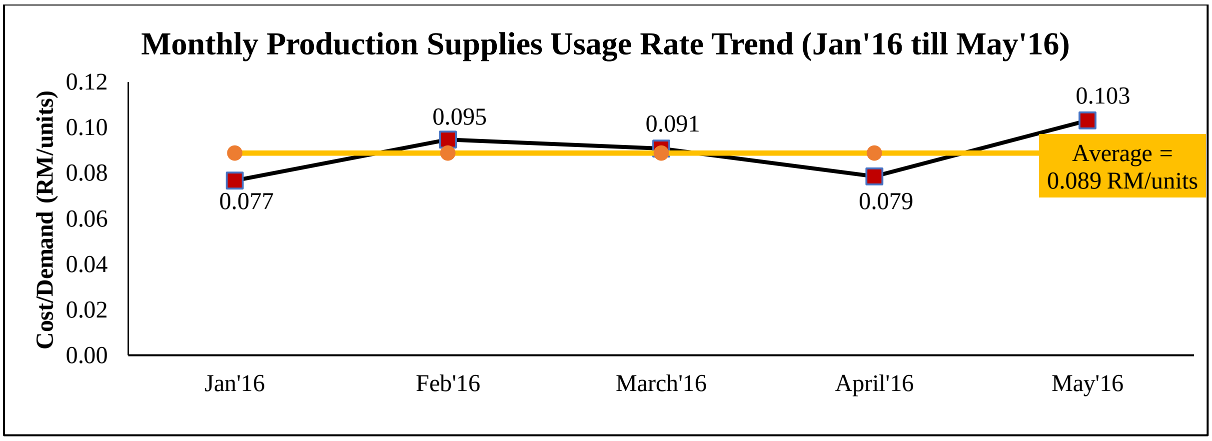

Figure 4 Monthly production supplies usage rate trend from Jan'16 till May'16

5.3 Conduct root cause & gap analysis

The selection was further refined. Prioritization matrix aimed to sort those ten production supplies into an order of importance. The priority of each item was derived by identifying their relative importance in term of effort required, impact on usage rate reduction, cost required and timeline required as shown in Table 1. Two selected items were CRR and BPU glove. The usage rate of CRR and BPU glove were shown in Figure 5 and Figure 6.

Quantum cell assembles voice coil into main frame of transducer. A layer of Mavidon epoxy is applied onto voice coil and requires significant curing time before proceeds to next level process. CRR is a metal cover. It aids in shortening the curing time by collecting more heat during heating process to raise the epoxy temperature. Operators are provided with BPU glove (heat resistant glove) to handle the CRR removal after complete curing, adhering to the ROHS regulation.

Table 1 Prioritization matrix used on top 10 production supplies

		CRITERIA - PRIORITY				
		Effort Required / Difficulty - 10 *High - 1* *Med - 3* *Low - 9*	**Impact on Usage Rate Reduction -10** *High - 9* *Med - 3* *Low - 1*	**Cost Required - 8** *High - 1* *Med - 3* *Low - 9*	**Timeline Required - 7** *High - 1* *Med - 3* *Low - 9*	*Score*
PRODUCTION SUPPLIES	CRR	9	9	9	9	315
	BPU Glove	9	9	9	3	273
	Touch N Tuff Glove (S)	9	3	9	3	213
	Touch N Tuff Glove (M)	9	3	9	3	213
	TIP, 1.6D, 900M	3	3	3	3	105
	Wrap BIT, 22AWG	3	3	3	1	91
	Wire Wrap Sleeve	1	3	1	1	55
	Resolver	1	3	1	1	55
	22GP .016 X .5 Blue	1	1	1	1	35

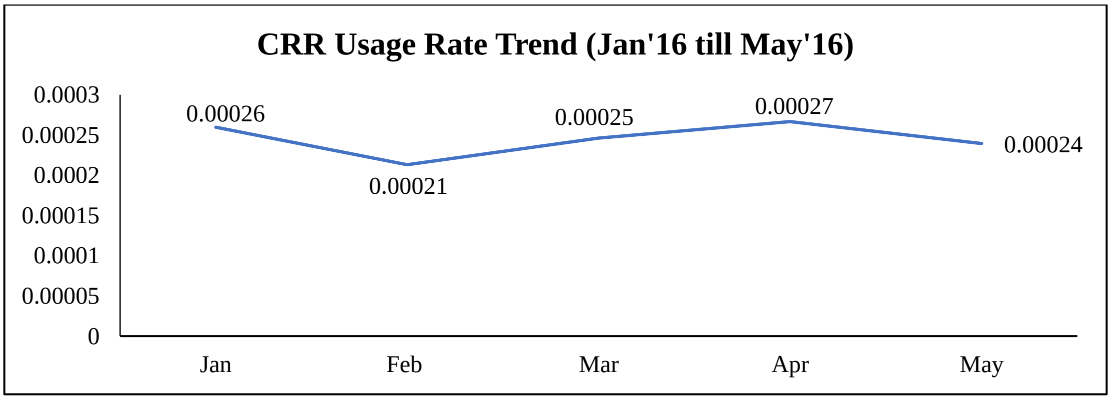

Figure 5 CRR usage rate trend from Jan'16 till May'16

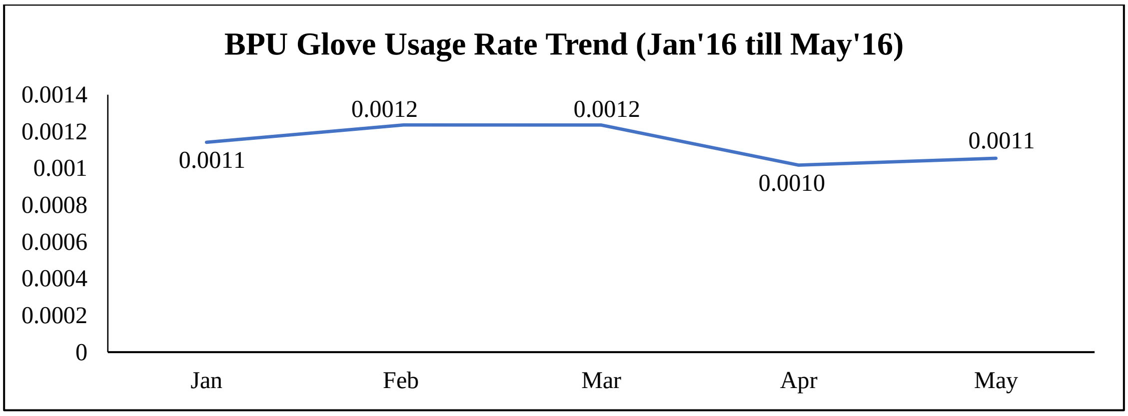

Figure 6 BPU glove usage rate trend from Jan'16 till May'16

The causes of high usage rate of CRR and BPU glove were identified using Fishbone diagrams, respectively shown in Figure 7 and Figure 8. These causes were categorized as measurement, method, machine, manpower, material and environment. Measurement is the design of Quantum cell layout. Method is the procedure that will influence characteristic of CRR or BPU glove. Machines are all those machines involved in Quantum cell. Manpower is the operator involved in Quantum cell. Material is the characteristic of CRR or BPU glove. Environment is the condition during operation.

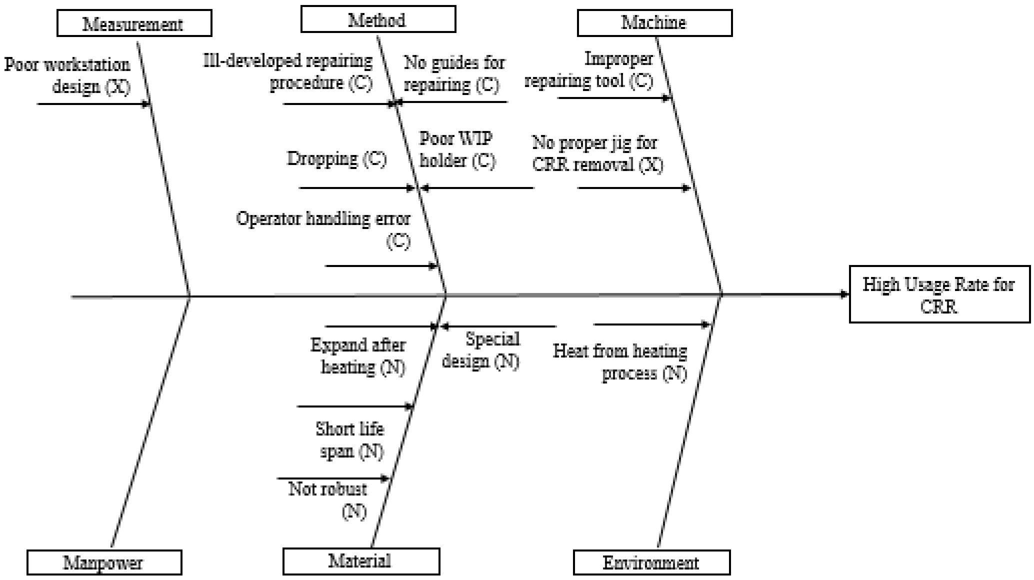

Figure 7 Fishbone diagram for high usage rate for CRR

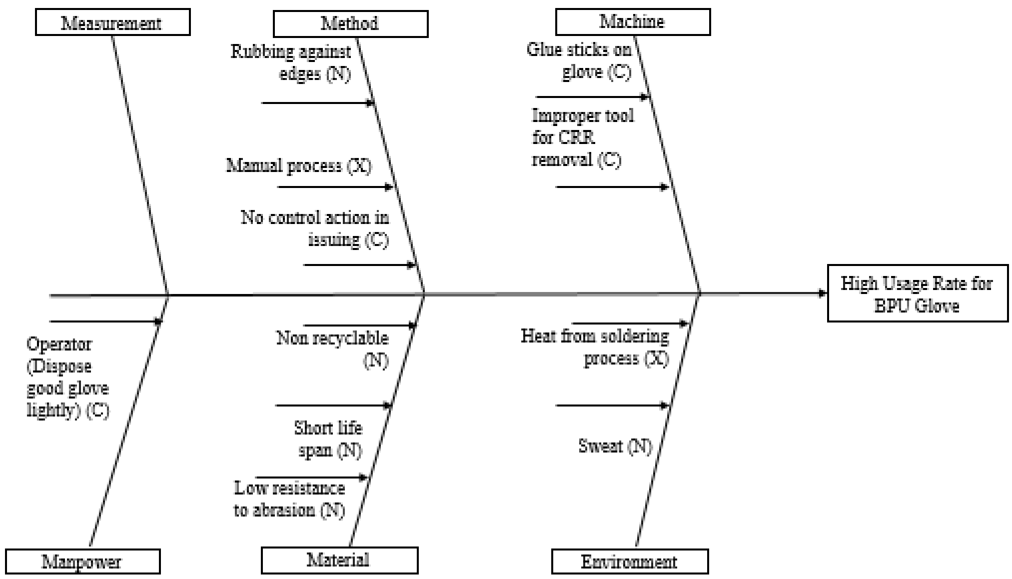

Figure 8 Fishbone diagram for high usage rate for BPU glove

5.3.1 Causes of high usage rate for CRR

Measurement

The Quantum cell layout runs three different products, mainly Revolver, Megadome and Superdome as shown in Figure 9. A common process is to assemble the voice coil to the main frame of the transducer. Revolver has a smaller voice coil and needs to undergo an additional offline workstation which dispenses Mavidon epoxy to the voice coil prior assembly process. Megadome and Superdome have larger main frame and inlock to hold the voice coil. The manufacturing process starts off from the assembly of CRR with the voice coil to the removal of CRR at the end of the process was further elaborated in Figure 10. Semi-assembled unit (CRR assembled with voice coil) will be transported between the offline workstation and the main route. Semi-assembled unit often fell off from the assembly line between offline workstation and the main route during the handling (averagely seven incidents per day).

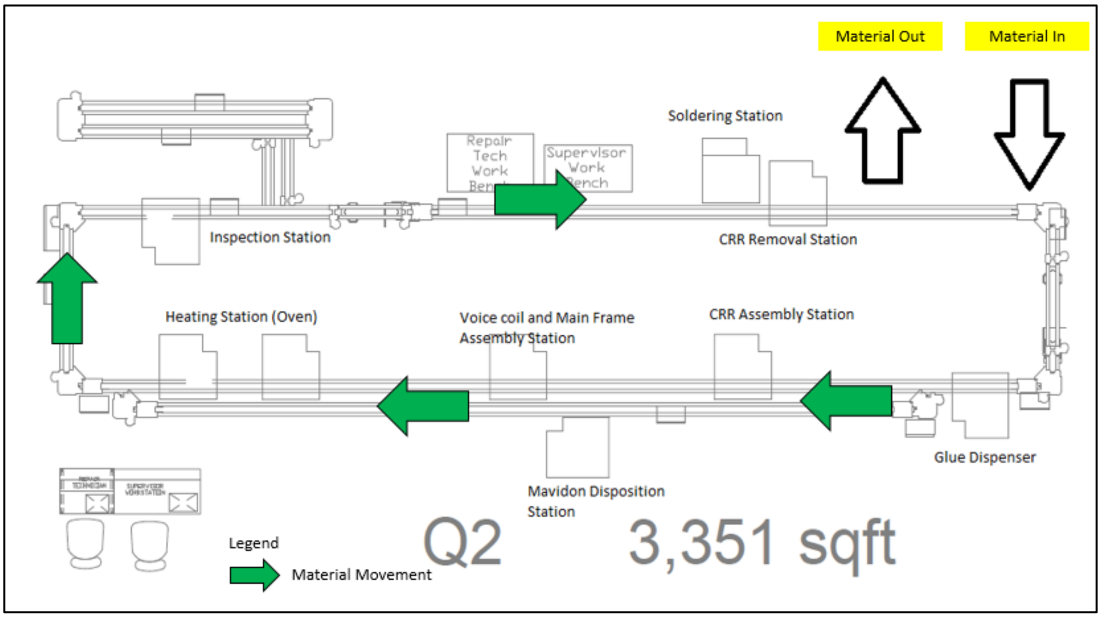

Figure 9 Material movement for manufacturing process of the Revolver. An additional Mavidon disposition station is between the CRR assembly station and voice coil and main frame assembly station.

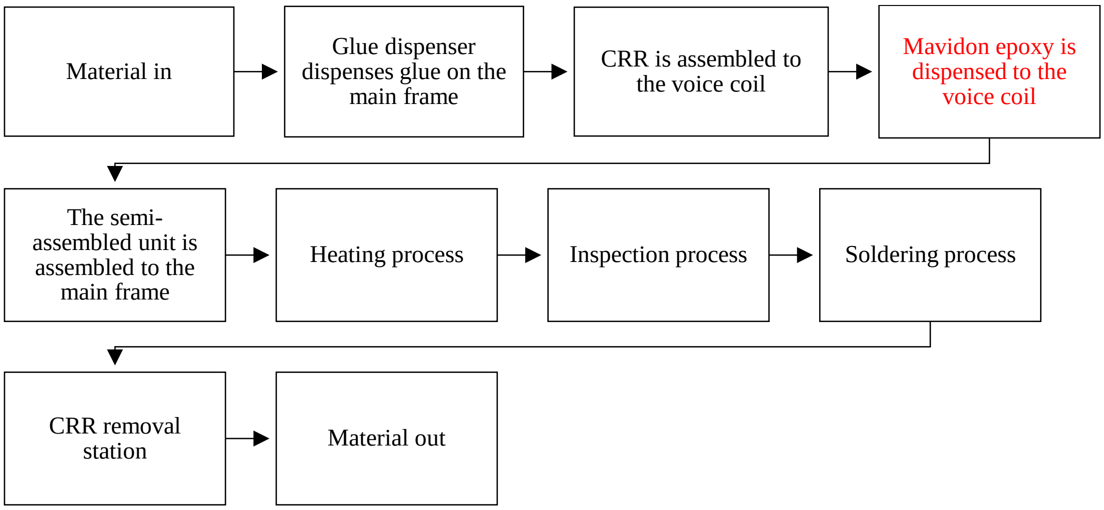

Figure 10 Material movement for manufacturing process of the Revolver. There is an additional Mavidon disposition station between the CRR assembly station and voice coil and main frame assembly station.

Method

The improper material handling method can be further elaborated as operator handling error and poor WIP holder under Method Fishbone diagram. At the CRR removal station, the CRR will be detached from the voice coil and later passed to the CRR assembly station, which was located opposite the CRR removal station. Both stations were facing opposite to one another to have a continuous exchange for the CRR. The passing over of CRR was being performed without using any proper WIP holder, which can potentially lead to high falling rate to the ground.

No documented work instruction for repairer to carry out repairing on the damaged CRR. The repairing operation was performed based on repairer's respective expertise and experience, which varied between one and another.

Machine

Operator exerted a certain amount of force to detach the CRR from the voice coil during the removal. Inappropriate force would damage the CRR.

A CRR could be repaired seven times approximately before scrapping. Improper tool was utilized to repair the damaged CRR and a repairing shaft was the only repairing tool. The