Scraps Management with Lean Six Sigma

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Abstract **- Increasing waste and scraps reflects low productivity as ratio input to output reduces. By all means, organizations are required to kick in with ultimate objective of cost reduction through process change to improve speed, low cost raw materials, revised preventive maintenance, and manpower reduction. Asian practitioners and western practitioners develop new approach to minimize waste and be cost effective in production. In the new millennium, the established methods developed in 20th century don't seem to suffice as demand volume increases. The call for the fusion of different methods to harvest the best of different methodologies has begun. Tools and approach used are not just effective but improve robustness in production processes as well. Bottom line contribution of the Lean Six Sigma approach manages scraps generating rate as well as improving throughput rate through wastes reduction.**
Keywords - *scrap management, lean six sigma*

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. In process of production, the output is usually outnumbered by input quantity producing goods and wastes. Another term used for the wastes are usually known as scraps. Technological advancement promotes demands and expectation from customers or voice of customer for flexibility. In turn, flexibility comes with a cost of byproducts if not designed properly. Many manufacturing industries strived to develop as effective as possible to minimize scraps with the goal of zero defects along the way. Many approach deemed to have come close in improving scraps management, preserving the profit margin or cost reduction for business stakeholders. The result of this development brought forth lean manufacturing and Six Sigma which are viewed as the transformation tools to save or improve business [1].
However, stagnated progress causes the efforts backslide itself. As economic inflation continues to rise and competition gets stiffer, managers and directors are required to cost down by all means possible while maintaining profit margin gained over time. Generally, most company managers will resort to lowering production cost by downsizing, cheaper raw material from different sources, reduction of preventive maintenance cost, and revamping production processes to save up space and overheads.

Just-in-time production (JIT) or also known as Toyota Production System (TPS), which was first introduced in the late 40's was one of the first-mover with most effective management and practice in operations [30],[11]. Originally developed by Taiichi Ohno, Shigeo Shingo and Eiji Toyoda, JIT served as a major precursor to lean manufacturing system that is widely encouraged to be practiced by product manufacturing industries (Toyota Production System and Lean Manufacturing, n.d.). TPS directly focus in identification of the waste in manufacturing to improve overall customer's value. Observing the steady growth Toyota to be one of the largest automaker, most major industries are impressed with the system practiced, hence made compulsory of this practice in their respective business due to its effectiveness in realizing systematic approach in production management [4]. The systemic approach developed in TPS eliminates queue time in repetitive batch manufacturing caused by high work in progress inventory [6].

While Asian practitioner maturated lean manufacturing system as an answer to cost reduction production system, westerners developed a set of tools and strategies known as Six Sigma for the purpose of process quality improvement. Six Sigma tools and strategies focus on process quality improvements by identification of causes of defects and variability reduction [2]. Compared to lean manufacturing, the statistical modeling through Six Sigma tools picture the problems and results of improvements more than JIT system does due to clear focus on achieving measurable and quantifiable goals set. Implemented by Jack Welch in 1995, Motorola's invention of Six Sigma tools and strategies in the 1980's has brought General Electric great business improvements and made known to most electric and electronic industries [24],[26]. Today, Six Sigma is adopted by many different sectors of industry by this historic business achievement.

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Although both systems has managed to improve productivity and driven cost of production down substantially initially, most industries failed to fully adopt the essence of both systems through effective innovation. The result was unconvincing enough to prove that either lean manufacturing practice or application of Six Sigma tools and strategies manage to drive defect rate close to zero. To add on, regulatory compliance cost reduces the net profit of the shareholders despite having loss at waste production. The ideal set in Six Sigma to achieve 3.4 defects per million opportunities (DPMO) was simply out of reach in most cases. As volume increases, though the yield number maybe close to 99.9%, the number did not justify the profit gained due to high volume of defects were produced at the same time. Further to that, the implementations of both systems were heavily criticized to have attracted extreme difficulties to operation managements [7]. To reduce the burden during implementations, [10] suggested that extensive detailed planning to be carried out in prior. Identification of critical points of implementation impact and sustainability are vital as part of critical success factors which would encourage in consideration of implementation plan development [16]. This is vital especially in complex technology firms with multiple models of processes.

This paper introduces a combination of both renowned methods of operation management tools and system, known as lean Six Sigma, innovated into an effective manner through systemic process control by production and scrap-pile inventory management. Tools of usual practitioner of lean Six Sigma such as SIPOC (supplier-inputs-process-outputs-consumers) framework, DMAIC (define-measure-analyze-improve-control) processes mapping, and root cause analysis (RCA) will be included as part of this management. The application of lean thinking and Six Sigma tools is viable in high variety low volume, high variety high volume and low variety high volume production firms as it takes into consideration based on discrete data obtained throughout production life cycle and production management experience.

2. Problem Statement

Increasing complexity of technology advancement resulted in complex processing steps adherence due to increase of number of variables [25]. In spite of technological advancement to minute sizing manufacturing, increasing demand from marketing encourages manufacturers to produce parts in high volume to fulfill the market demands. Manufacturers adheres to the timeline given by marketing team, hence, pushes for outputs while risking trading off qualities and producing relatively high amounts of unintentional byproducts. Poor quality products resulted in customers' voicing to suppliers, reducing the trust in the reliability of the manufacturers. Voice of customers is usually perceived as customers' expectation [8]. Looking into these factors of loss of profits, top management creates a pressure to operation team for improvements in output quality as well as minimizing cycle time to lower overhead costs and indirectly exceed customer's expectation in delivery lead time.

Manufacturing tends to have the largest share of regulatory compliance cost with respect to other industries [27]. Manufacturing industries have suffered spending billions to comply with economic, environmental and workplace safety regulations implied. New "green" systems are bought in off the shelf and applied directly with annual costing to keep the system running. Lack in maintenance in "off-the-shelf" system results in environment control malfunction, hence generating undesired products. This is especially true to factories that practices "clean-room" environment. Contaminated products are bound to scrap yard inducing losses to stakeholders.

Typical steps taken by most manufacturing industries are such as batch manufacturing, and line dedication to increase productivity in hope that throughput time is reduced. Generally, queue time takes about 80 percent out of the whole total throughput time in repetitive batch manufacturing [6]. The root cause of the increasing queue time is due to the high work in progress (WIP) inventory. Ultimately, this did not give significant improvements to the expectation by top management in lower cycle time.

Aside from high WIP inventory, high inventory in stores for raw materials and goods leads to material aging. Manufacturers assume stable demands from the market and stable part demands from variable market to create an assembly shop plan for final products. This eases the application of batch manufacturing whereby the store would receive and supplying parts in batches to assembly floor [12]. In practice, the market demands and part demands from variable markets are not flat. They fluctuate in accordance to economic, environmental and social factors. As such, high inventories would, in time, turn into scraps due to obsoleting and or aging.

In a high volume and high mixing of product types environment, traceability system is important to ensure the right products is shipped to the customers. However, manual transactions in production line logistics is not fool proofed, hence, tend to possess high possibility in product mixing and loss of traceability. However, to ensure customer will not receive wrong product, operation team will perform batch scrapping. The scrapping of untraceable units is viewed as unnecessary profit loss as these units are in fact, functional and cosmetically good.

Other issue which promotes incremental of scraps comes from engineering of ergonomics practiced by operators. Poor ergonomics discourages operators to abide by process flow designed, in other words, prone to skip processes to achieve the targeted output. Poor ergonomics, too, demands a high skill of operation. Manufacturing industries with high attrition rate suffers with low skill operators, producing low quality outputs with high rejection rate. The ideal objective of Six Sigma achieving

3.4 defects per million opportunities (DPMO) is remained theoretically right.

3. Literature Review

Lean Six Sigma is a concept combined between lean and six sigma theory. The objective of this combination is to harvest the best of both aims. Lean reduces or eliminates the identified waste on resources conducted while Six Sigma achieves 3.4 defects per million rate output in each side of distribution of goods and services. [14].

3.1 Lean

Lean functions as a set of tools to identify and eliminate waste in production system. [18] identified seven types of waste that occurs in firms and industries. The wastes identified are defects, overproduction, inventories, unnecessary processing, unnecessary movement, unnecessary transport, and waiting. [29] added that having designs of products and services that does not meet end users' needs and wants is another severe waste aside from the seven identified by Ohno.

In the principles of lean, [29] stated that product and service value is only meaningful if expressed in monetary value and in terms of product or service specification or both by customers. Identification of "Value Added" (VA) and "Non-Value Added" (NVA) activities becomes essential to eliminate waste of movement, processing, transporting and resources. By carrying out a mapping stream, such identification will be surfaced. A summation of the total time work done that adds value as oppose to the total time it takes to produce an item will give rise to the level of waste in the system [29]. [29] also indicated that creating a smooth flow of production is required to minimize or eliminate waiting time or lead time. The current flow of production can be set up either by push or pull system. In lean principle, [29] suggest that pull system is preferred over push system to avoid traffic congestion in the event of low downstream demand. The final lean principle derived is continuous refinement of value stream by understanding customers' perceived value to increase current flow. The principle is similar to *kaizen* practice.

3.2 Six Sigma

Six Sigma describes a process performance quantitatively by setting a goal of 3.4 defects per million opportunities (DPMO). Six Sigma projects usually are accomplished through two sub-methodologies known as DMAIC (Define, Measure, Analyze, Improve, Control) and DMADV (Define, Measure, Analyze, Design, Verify).

DMAIC is driven by data for process improvement in optimization and stabilization. The purpose of define is to clearly identify the problem statement, goal, available resources, timeline and scope area. Information such as voice of customers, project goals and management directions are critical in defining process to set target performance. Generally, define phase calls to address questions regarding problem statement, goal identification, customer identification, CTQs (Critical to Quality) in-concern, and process under investigation [23]. The measure phase is interested in vital aspects of the current state provide a benchmark on where the project stands. It also serves as tool to on root cause identification by noting the vital few root causes by addressing to the key data. Analyze phase focuses on exploratory analysis and inferential analysis. Through both analyses, key process input variables (KPIV) which causes the defects are identified. A flow diagram of analyze phase can be depicted as in Figure 1.

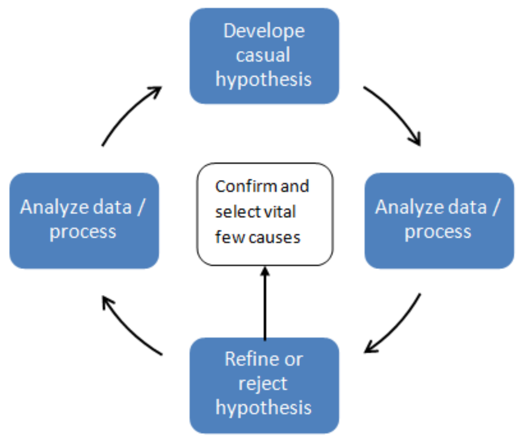

Figure 1. Flow of analyze phase
(Source: Modified from *Six Sigma: Advance Tools for Black Belts and Master Black Belts*, 2006)

The improve phase focuses on quantification of limits in key process inputs variables (KPIV) or the independent variables which influence the CTQ of dependant variables. Improve phase seeks for potential ideas for lowest possible cost of solutions with high effectiveness upon implementation. In control phase, continuous monitoring on key process output variables (KPOV) to facilitate high consistency of quality goods and service is carried out. To place DMAIC framework into practice, techniques such as quality deployment, failure mode and effect analysis (FMEA), design of experiments (DOE), and statistical process control (SPC) are integrated to form the DMAIC flow mentioned earlier [23].

In practice, implementation of Six Sigma poses several limitations. This includes high dependence on measurements and often neglect unquantifiable parameters, negligence to outliers or irregular outcomes, focuses on precaution steps for errors, basic CTQ centered, low variation studies on external parameters in projects, low self-empowerment, relevant only to repetitive goods and service industries, prioritize organization profitability sustainability and maintenance over people development, and tends to form internally profitable objectives only.

3.3 Lean Six Sigma

By combining Lean concept and Six Sigma concept, it would result in quicker and achieve best competitive position in concentration of the use of effective tools established. The complementary of both Lean and Six Sigma can be summarized to as the following Table 1.

Table 1. Complementary points of Lean Manufacturing and Six Sigma Methodology

Lean	Six Sigma
Efficiency focused	Effectiveness focused
Waste reduction targeting	Variation reduction targeting
Value stream based	Subset of value stream based (detailed process)
Operational metric	Quality metric
Continuous improvement	Breakthrough improvement
Experience driven / Intuitive	Data driven / Statistical
Marco view	Micro view
Flow & Speed oriented	Capability & Accuracy oriented
Reduction number of steps	Reduction of variation in process
Reduce inventory	Reduce rework
Implements known solution	Implements innovated or creative solution
Low complexity problem effective	High complexity problem effective
Short project duration	Longer project duration
Targets "low hanging fruits"	Targets "long shots" achievement
Cost volume lost upon failure	Cost quality lost upon failure

The aim in Lean Six Sigma is growth centric which includes cost reduction and productivity improvements. The fusion of Lean and Six Sigma is required because in general, Lean aims to create value through elimination of waste while Six Sigma aims to meet quality demands from customers' need [3]. A sample of significance of Lean Six Sigma can be presented in Figure 2. The chart in Figure 2 illustrates the improvements in overall yield at varying sigma level.

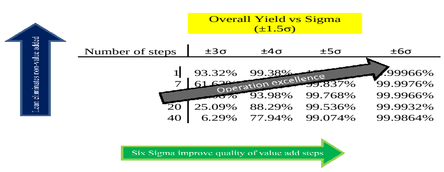

Figure 2: Lean process that operates at Six Sigma Capability
(Source: Modified from *Lean Six Sigma Institute: What is Lean Six Sigma?*)

[28] reported in "Root Cause Analysis: An essential element of Asset Integrity Management and Reliability Centered Maintenance Procedure", that traditional maintenance strategies neglects identification and correction of the root problems. The maintenance planning since the beginning was more of reactive, thus the practice of "Run-To-Fail" (RTF) maintenance. As research in better maintenance practice advance, new methodology was founded such as periodic maintenance, predictive maintenance (condition monitoring maintenance), and proactive maintenance strategies through root cause failure analysis. However, wrong selection of maintenance will either induce too much cost on component change or more rejects are produced, hence wastes. Analysis to weigh between the cost and benefit of each maintenance plan selection is crucial to improve production speed, lowering machine downtimes, and maintaining throughput quality.

In the new era of manufacturing, Agile manufacturing calls for high flexibility to meet short response time to customer's demands. At the same time, each customers' demand disparity increases difficulty level in practicing smooth production flow. High product mix occurs resulting in multimodel facilities requirement in the same layout [13]. Scheduling factors the turbulence of establishment of lean manufacturing as well. Without smooth transition in schedule change, production experiences hiccups and non-linear loading of raw materials and demands. Changes usually occur as time is close to delivery point of time [13]. In practice, the quality of short conversion time is directly proportional to the robustness of production processes. Poor flexibility of the production process will induce more byproducts as more resources are required to complete the job.

[19] observed in industrial and technological scenario that control or supervision architectures are not sufficiently efficient to minimize time and resource waste generated in production. Hence, the lack of control system quality impacts material aging, as a result of high production downtime. In another area of production, store management has a significant impact in material aging as well. Aged materials often have reliability concerns and will lead to more production defects [20]. The correlation between production defects to material aging is as in Figure 3.

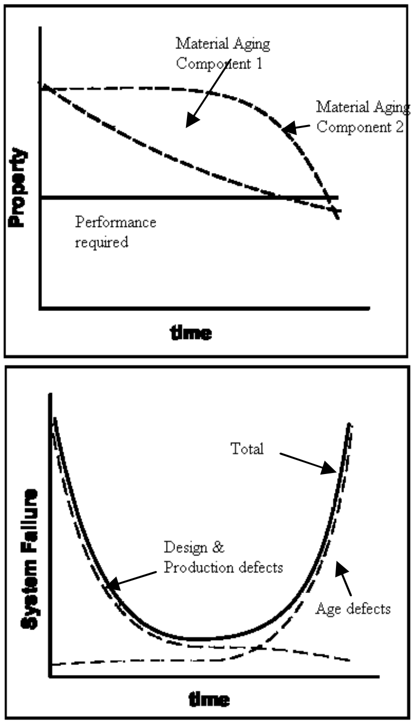

Figure 3: The predicted result of material aging against total defects output
(Source: Adapted from work of Salzbrenner, n.d.)

[17] accounted human factor as part of reason for wide distribution of goods quality. Various skill levels produce different quality of output despite the similarity of process steps and procedures. As production management pushes for throughput volume, operators are pressured in delivering the demands. Correlation between production speed and quality is weak given repeatability and reproducibility gauged is fairly low. Often, this will result in producing defects and extra consumption of resources. Examples of waste generated due to poor processing are transaction process, bad ergonomics, and manual product labeling.

4. Application of Lean Six Sigma Framework

Identification of the possible causes of increasing rejection rate resulting in scraps can be done via 4M (Man, Machine, Method, Material) and 1E (Environment) root cause analysis. As such, the framework can be identified to as follow.

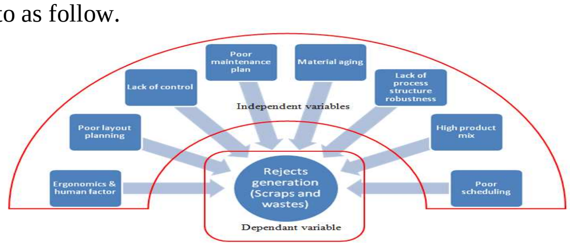

Figure 3: The factors resulting in increasing scraps and wastes at production shop-floor
(Source: Adapted from work of Jina *et al* (1997), NRC & Nickerson (1995), Tronskar (n.d.), Onori & Olivera (2010), Salzbrenner (n.d.))

From the identification above, improved process and operations can be planned through DMAIC framework. DMAIC methodology pulls together information such as data, customer, quality, speed, and norms of processes in the organization. Identification of the above can be further elaborated using SIPOC (Supplier, Inputs, Process, Outputs, Customers, Requirements) diagram to define an optimized process and operation.

Process performance will be measured by several operational metrics to reflect the health of the process:

- Metric should be related to variable in achieving higher success, mission, vision and values of current and future production operation performs
- Metric applicable to all sectors of productions
- Metric changes as strategy changes

The value stream selection begins with the highest potential increase of shareholder value per investment of resource [9]. As such, prioritizing the independent variables by cost and ROIC (Return On Invested Capital) is essential. Each process is to mapped the Net Present Value (NPV) to identify the discounted cash flows to ROIC and revenue growth. The formula derived is as follow:

$$Value = \frac{No(1-G/R)}{(1+W)} + \frac{No(1-G/R)(1+G)}{(1+W)^2} + \frac{No(1-G/R)(1+G)^2}{(1+W)^2} + ...$$

$$= \sum_{n=1}^{N} \frac{No(1-G/R)(1+G)^{n-1}}{(1+W)^n}$$

where G = growth rate %, R= ROIC %, W = cost of capital %

(Source: *George*, 2002*)*

NPV implicitly links to performance to customers' reaction to products or service, which directly implies Voice of Customer (VOC).

With work done on prioritized valued processes, manufacturers often face problems in delivery speed. Engineering often places multiple gating, detailed sophisticated processes through combination of different theories and increased non-value added designs to prevent rejects in production or reworking processes. Empowering the designed process with lean means improving the throughput speed. To identify the factors for lost of momentum, [9] suggested identification of starting point by 80 / 20 rule. Pareto principles emphasize on high volume of observation data which assist in identification of 20% improvement to effect 80% reduction of lost momentum. The next value stream mapping in each process in detail can be conducted by:

- Visualize process levels
- Highlight wasted resources
- Mark hidden points

The processes above repeats in detail, zooming down to as close as possible in accordance to level as portrayed below:

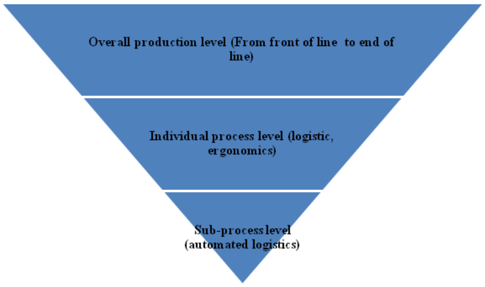

Figure 4: Levels of organizational process in a typical manufacturing firm

To identify the effectiveness of applied Lean Six Sigma, historical productivity data of established organization that applies the principles of Lean Six Sigma can be evaluated through statistical tool, SAS JMP.

5. Discussion and Implication

The success of Lean Six Sigma approach is perhaps the most notable approach in many manufacturing organizations today. Efficiency and effectiveness is both tackled at the same time to maximize productivity and minimize wastes. Ingeroll Rand Security Technology increased their throughput by 70 percent by defect reduction, shifting sigma level from 0.5 to 3.53 [5]. The DMAIC approach improved overall processes through identifications of strength and weakness in detailed manner. Meanwhile, other Six Sigma tools such as SIPOC and process mappings discretely show the vital points in making the process better. Fusion of both working in parallel delivers value to customers and generates significant gains for the organization. Other industry such as Acme Industries adopted Six Sigma to improve pricing quality [21]. In Acme Industry, the tools used are slightly different from what have been used in Ingeroll Rand Security Technology, which is the use of failure mode and effect analysis. Acme Industries analyze the failure reasons and immediately place counter action plans to vital few conditions, such as customer response time and pricing variation [21].

6. Conclusion

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. Clear definition of problem statement, measured values and proper control implied ultimately secures situation firmly. Bottom line of the Lean Six Sigma approach manages scraps generating rate as well as improving throughput rate through wastes reduction. It is recommendable in most business application in operation management.

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