VEHICLE COLOR GLOSSINESS STUDY USING SPC IN AN AUTOMOTIVE MANUFACTURING COMPANY

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ABSTRAK

Tahap kekilatan warna pada panel badan kenderaan adalah salah satu faktor yang sangat penting dalam menentukan kejayaan penjualan kenderaan tersebut. Berdasarkan kepada kenyataan ini, satu lawatan ke Malaysian Truck and Bus Sdn. Bhd (MTB) telah dijalankan. Lawatan ini bertujuan mengenalpasti masalah berkenaan banyak skrap (kerja semula) terhasil daripada proses mengecat. Menurut MTB, sebanyak RM1100 sebulan atau RM 13200 setahun telah diperuntukkan untuk membaik pulih kecacatan ke atas kualiti mengecat yang dikesan. Oleh yang demikian, laporan projek ini adalah mengenai analisis kualiti ke atas mutu kekilatan cat menggunakan kaedah Kawalan Proses Statistikal (SPC). SPC direka sebagai salah satu langkah pencegahan terhadap variasi dalam proses pembuatan. Dengan menggunakan kaedah SPC terutamanya carta $\bar{x}$ dan R dan kajian kapabiliti (indek C_p dan C_{pk}), variasi yang berlaku di dalam proses mengecat yang disebabkan oleh *'assignable cause'* telah dikenal pasti. Manusia, Mesin, Bahan (material) dan Metodologi adalah faktor yang menyumbang ke arah kewujudan *'assignable cause'*. Keseluruhannya, proses mengecat kenderaan Mitsubishi Storm warna metallic ini berada pada situasi luar kawalan dimana terdapat banyak titik plot dalam sebaris berada di bawah garisan tengah disamping titik yang berada diluar had kawalan proses. Keadaan ini dikenalpasti sebagai paten tidak natural (unnatural pattern). Kesan faktor 4M ini ke atas proses mengecat menyebabkan nilai-nilai indek kapabiliti C_p dan C_{pk} yang diperolehi adalah agak rendah daripada sepatutnya dimana nilai sebenar C_p = 1.22 dan C_{pk} = 0.94 dan nilai sepatutnya ialah C_p = 1.33 dan C_{pk} = 1.00. Berdasarkan faktor-faktor 4M, suatu langkah pencegahan dan pembetulan dirangka bagi mengembalikan nilai purata proses kepada menjadi hampir atau sama dengan nilai purata spesifikasi dan beberapa kaedah penyelesaian telah diusulkan.

ABSTRACT

High quality glossiness color for exterior body panel is critical to the success of automobile sales because of the impact on the purchasing decision is relying on the coating. Based on this statement, a visit to Malaysian Truck and Bus Sdn. Bhd. (MTB) has been conducted. This visit regarding many reworks is produced in coating process on the metallic color Mitsubishi Storm model vehicle. The reworks occurred when the process failed to meet designated specification limit. As calculated, there is about RM1100 a month or RM13200 annum is spent for bad quality coating. Therefore, this project has undertaken analysis and report on the statistical process control (SPC) in the company to address this issue. SPC is invented as a prevention tool to monitor manufacturing processes and becoming framework for preventive action. By using SPC tools specifically the $\bar{x}$ and R chart and capability study which is the C_p and C_{pk} indices in this particular study, variation due to assignable causes in the process has been identified where the 4M; Men, Machines, Methods and Materials, causes become the main sources of variation. The C_p index shows how well the process spread is compared to the specification spread and the C_{pk} index shows whether the process is producing reject or not. Analysis has showed that the painting process is in out-of-control situation. Even the C_p index is 1.22 which is more than 1.00, the pattern on the control chart showing the unnatural ran process where many points in a row fell below the centerline and some points located beyond the control limits. The C_{pk} index value is 0.94 and showing that rejects are produced in the process. The variations cause the C_p and the C_{pk} indices value are lesser than expected value which are C_p = 1.33, and C_{pk} = 1.00. Prevention action and countermeasures are proposed in order to get the process back on its target based on the effect of the 4M.

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LIST OF SYMBOLS

$\bar{\bar{x}}$	-	Average of the subgroup averages
$\bar{x}_i$	-	Average of ith subgroup
m	-	Number of subgroups
UCL	-	Upper control limit
LCL	-	Lower control limit
$\sigma_{\bar{x}}$	-	Population standard deviation of the subgroup averages
$\bar{R}$	-	Average of the ranges
R_i	-	Individual range value for the sample
A_2	-	Approximation factor used to calculate control limits
σ_R	-	Population standard deviation of the subgroup ranges
D_3	-	Approximation factor used to calculate range chart control limits
D_4	-	Approximation factor used to calculate range chart control limits
PCR	-	Process capability ratio
6s	-	6-sigma
CR	-	Capability ratio
USL	-	Upper specification limit
LSL	-	Lower specification limit
σ	-	Standard deviation
C_p	-	Capability index
C_{pk}	-	Capability Index
C_{PU}	-	Single sided process spread capability index
C_{PL}	-	Single sided process spread capability index

T	-	Tolerance (Specification tolerance)
d_2	-	Approximation factor for calculating within subgroup standard deviation

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CHAPTER 1

INTRODUCTION

1.1 Statistical Process Control (SPC)

Today's automotive supplier industry competes in a global economy that imposes rigorous and ever-increasing quality standards. Growing numbers of competitive manufacturers are exposing quality. Dedication to constant improvement in quality and productivity must be emphasized by each competing company. The quality of the product has to be world class, as good as the best in the world, in order to compete. Consumers are looking for the best combination of price and quality before buying. The 'Made in Malaysia' or even the giant brand 'Made in the USA' labels are no longer enough to sell a product. If Malaysian companies want to succeed in a global market, their product must be competitive. Nowadays, each company employee must be committed to the use of effective methods to achieve optimum efficiency, productivity and quality to produce competitive goods. Due to each company competing against each other to produce competitive goods, certainly, everyone has felt the push from management and the pull from customers for improved quality. Thus, the consistent, aggressive and committed use of Statistical Process Control (SPC) to bring all processes under control, recognize and eliminate special causes of variation, and identify the capability of all operations is a key requirement. SPC is defined as prevention of defects by applying statistical methods to control the process [Summers, (2003)]. Others define SPC as a procedure in which a data is collected, organized, analyzed and interpreted so that a process can be maintained at its present level of quality or improved to a higher level of quality [Smith, (2004)].

When a company produces a product or service, it utilizes many interrelated processes and each process involves several to many steps to accomplish a specific task. There may be several sources of data available as the task is undertaken and measurements that have to be within specified limits or outcomes to be judged acceptable or not-acceptable. All the different processes are combined to yield the final product or service.

SPC can be applied whenever work is being done. Initially, it was applied to just production processes, but is has evolved to the point where it is applied to any work situation where data can be gathered. As companies work toward a total quality goal, SPC is used in more diverse situations.

SPC involves the use of statistical signals to identify sources of variation, to improve performance and to maintain control of processes at higher quality levels. The statistical concepts that are applied in SPC are very basic and can be learned by everyone in the organization. All workers must know how SPC applies to their specific jobs and how it can be used to improve their output.

SPC does not meant to workers only but supervisors also must acknowledge to the use of SPC. Supervisors must be aware of the ways SPC can be used in their sections, be prepared to help their production workers utilize SPC and be receptive to suggestion for improvements from the workers who are effectively using SPC. Manager also must know how SPC can be used to improve quality and productivity simultaneously. When supervisors recommend process changes based on SPC analysis and interpretation, managers must understand the SPC concepts in order to make knowledgeable decisions. The company must create and maintain a management style that emphasizes communication and cooperation between levels and between departments. The goal must be set to develop a working atmosphere that maximizes everyone's contribution to the production of competitive products.

Implementing SPC in manufacturing process is crucial as SPC will increase the product quality and hence reduce the total rework and scrap costs. SPC is the best prevention action where any out-of-control or unnatural process can be traced and prevention countermeasure can be done in order to prevent the process producing rejects. Hence, the purpose of implementing SPC in manufacturing process enables the company to reduce reject costs and improve their product quality through low cost monitoring process, the SPC.

1.2 Prevention versus Detection

One of the major problems in manufacturing today is that some companies' version of quality control is simply to find defective items after they are made and remove them before shipment to the customer. When mistakes are found in service industries, documents are redone and corrected. If the mistakes involved the customer, apologies must be made. These are examples of trying to achieve quality through the detection method. The quality of the system has not improved, even though some inferior products were weeded out or some mistakes were found and corrected. SPC on the other hand leads to a system of prevention. SPC emphasizes the prevention of defects rather than detection. Prevention refers to those activities designed to prevent defects, defectives and nonconformance in products and services. The most significance difference between prevention and inspection is that with prevention, the process rather than solely the product is monitored, controlled and adjusted to ensure correct performance.

Detection models, as Fig. 1 illustrates, usually rely on a corps of inspectors to check the product at various stages of production and catch errors. This quality control method is inadequate and wasteful. Money, time and materials are invested in products or services that are not always usable or satisfactory. After the fact inspection is uneconomical and unreliable. Inspection without analysis of the process and subsequent action neither improves nor maintains product quality. Inspection plans cannot find all the defective items, and the waste is appalling. The company pays an employee to make the defective item and then pays the inspectors to try to find it. If the inspectors find it, the company pays another employee to fix it. Also, defective products that are not found lead to warranty costs, damaged reputation and cancelled orders. Unless action is taken to correct the faulty process, the percentage of the output that is defective will remain constant.

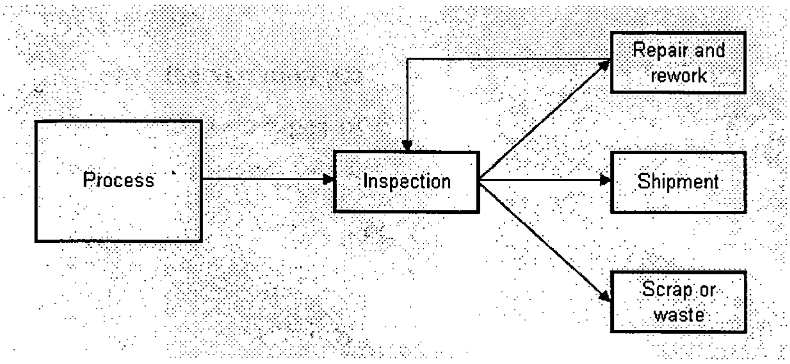

Fig. 1: The detection model [Smith, (2004)].

The prevention model uses statistical signals at appropriate points in the process to improve the procedure and to maintain control at the improved level. Statistical signal provide an efficient method for analyzing a process to indicate where improvements should be made to prevent the manufacture of defective items and to improve the quality of the items produced. This is illustrated as in Fig. 2. Prevention avoids waste. If the product is not flawless at the first time, fix the process so that the products will be right again the next time. The process then monitored so that needed adjustments can be made before quality suffers.

SPC is becoming the core for both quality improvement and quality maintenance. Important decisions from optimum adjustment time decisions made at the shop floor level to process change decisions made by management involve SPC. Statistical method and techniques, such as control chart analysis of a process or its output, are now being used extensively to make economically sound decisions. The process analysis leads to appropriate actions for achieving and maintaining a state of statistical control and for reducing process variability.

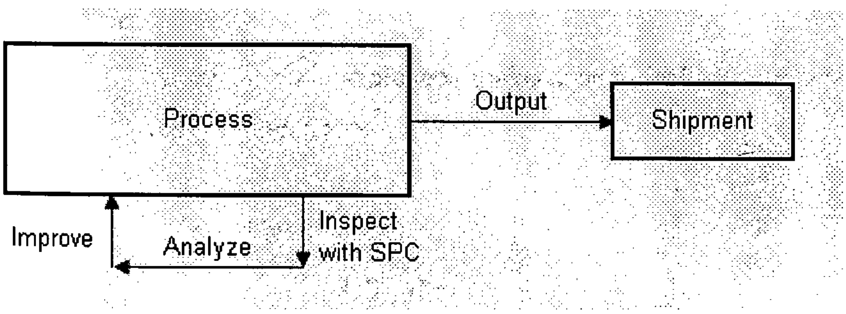

Fig. 2: The prevention model [Smith, (2004)].

1.3 The Need for SPC

SPC also seeks to limit the variation present in the item being produced or the service being provided. There are two types of variation; common-cause and special-cause. While it once was considered acceptable to produce part that fell somewhere between the specification limits, SPC seeks to produce part as close to the nominal dimension as possible and to provide services of consistent quality from customer to customer. To relate loss to only those costs incurred when a product or service fails to meet specifications is unrealistic. The losses may be due to reduced performance levels, marginal customer service, a slightly shorter product life cycle, lower product reliability, or a greater number of repairs. It ca be simplified that losses occur when the customer has a less-than-optimal experience with the product or service. This is because the larger the deviation from the desired value, the greater the losses. These losses occurred regardless of whatever or not the specifications have been met. Reducing process variation is important because any reduction in variation will lead to a corresponding reduction in loss. SPC goals can be described as follows:

- Minimize production costs. This goal is accomplished by "make it right the first time" program. This type of program can eliminate costs associated with making, finding and repairing or scrapping substandard products.
- Attain a consistency of products and services that will meet production specifications and customer expectations. Reduce product variability to a level that is well within specifications so the process output will match the desired design quality. This consistency leads to process predictability, which benefits the company by helping management meet quantity targets.
- Create opportunities for all members of organization to contribute to quality improvement.
- Help both management and employees make economically sound decisions about actions affecting the process.

SPC goals also can be adopted by company as their quality statement mission. This is due to currently almost all companies have such statement in their company's visions. As stated earlier, SPC can be used by both management and production people because it includes statistical methods that utilize the expertise of all employees of the company by problem solving. Management can use SPC as an effective tool for reducing operating costs and improving quality by using its methods for organizing and implementing the quality effort. The various processes can be charted and product flow can be analyzed at any point of the process. Bottlenecks and quality problems can be pinpointed quickly for management planning and solutions. The capability of the processes to attain desired quality levels could be analyzed statistically for management decisions regarding overhaul or replacement of machinery. Analysis of control of charts can lead to training, retraining or reassignment decisions regarding production workers. Management decision on recommendations for process changes can be based on a combination of statistical analysis and cost analysis. The entire process becomes predictable so managers can achieve better planning for quantity targets. SPC creates a new management philosophy: Lines of communication are opened among all employee levels for the betterment of the company and the product.

SPC also works for production employees. These employees can use SPC to develop effective tools to work more efficiently (not necessarily harder but worm smarter and effectively). When employees learn SPC, they worked more intelligently. They know from their control charts when they are doing a good job. SPC gives them a good opportunity to influence work operations and be responsible for their jobs. It can help increase employees' pride in their work by allowing them input into the production process. Production workers are often the most qualified employees to determine what is wrong and what is right with their particular step in the process. As contributing members of a process control team, they can help with quality improvement.

1.4 Objectives

Three specific objectives have been defined to simplify the main objective of the project. There are:

i. To carry-out a case study of glossiness quality of a vehicle.
ii. To implement a quality control technique for a selected vehicle body panel.
iii. To propose some improvement on coating process from the study.

1.5 Scope of Study

The scope defines the manufacturer background, boundary and population of the process to be study. The scopes of study are:

1. A literature review has been conducted to determine the best quality tool.
2. A case study has been conducted on current coating process in Malaysian Truck and Bus Sdn. Bhd.
3. To analyze the collected metallic color glossiness data from Mitsubishi Storm model vehicle.

These definitions are essentially needed to narrow down the study scope from the wide topic of SPC.

Manufacturer: MALAYSIAN TRUCK & BUS SDN. BHD.

Boundaries: SPC includes those tools used during production to eliminate unexpected causes of variation. Type of taken data is metallic color glossy rate on the right side of the studied vehicle's body.

Population: The study subject is production of Metallic Color Mitsubishi Storm vehicle using brand NIPPON paint and lacquer.

Time period: One month data, taken from the production of studied subject.

CHAPTER 2

BACKGROUND

2.1 Applying SPC to an Existing Manufacturing Process

When SPC is introduced to a process, the initial thought should be about the quality characteristics. What are they and what are their associated measurement requirements? In most situations, a statistical quality control (SQC) analysis would be done first by identifying the quality characteristics are critical to quality (CTQ) and determining how those characteristics can be controlled. As an example, when an automobile transmission or a four-wheel-drive transfer case is made, one of the quality characteristics is the noise (or lack of it) at various speeds. The SQC analysis of the noise at specific speeds could then lead to several SPC charts of CTQ measurements in the manufacture of the gears that would contribute to the noise factor. Below are the steps in brief of existing SPC in manufacturing process.

1. The initial step in SPC is diagramming and analyzing the process to decide where control charts may be best to applied.
2. Decrease any obvious variability in the target process.
3. The third step involves statistically testing the gauges using a gauge capability study. This must be done before measurements are taken for control charting. The variation that shows up on the control charts must reflect the process variation that needs to be reduced.
4. Make a sampling plan. Determine the size of the sample and when the samples are to be taken.

5. By using the control chart, find the out-of-control situation caused by common-cause and special-cause, evaluates what happened at that specific time to cause it, and then work to prevent that cause. This procedure continues until the control chart indicates that there are no more special-cause variation problems. By this time, the process is running as well as it possibly can without process modifications and it is said to be in statistical control.
6. The sixth step is to put operator in-charged. This step and step 5 actually occurred simultaneously because the operator should be doing the control charting and attaining statistical control with the help of the process control team.
7. This step is to determine how capable the process is according to product specifications and customer expectations.
8. This step is designed to improve the process. Eighty-five percent or more of the process problems are handheld at this stage, according to quality consultant W. Edwards Deming. At this stage, process changes can be analyzed on control charts either singly or in variable interaction studies for signs of process improvement. Designed experiments may also be used in the search for improvements. When improvements are found, management must follow thru and see the appropriate changes are incorporated in the process without backsliding.
9. The ninth step calls for a switch to pre-control, a monitoring technique that compares a measurement with target and warning measurements, when the process is in control and capable.
10. Quality improvement is a continuous process. Two things should be done at this step; first, continue to look for ways to improve the process at hand and second, return to step 1 for the next critical measurement.

Historically, many companies did not begin using SPC until they were forced. Either they could see their competitive position diminishing or they were obliged to meet their customer's requirement that contracts would not be awarded until their workforce was trained in SPC. Unfortunately, some companies just met the minimum

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Historically, many companies did not begin using SPC until they were forced. Either they could see their competitive position diminishing or they were obliged to meet their customer's requirement that contracts would not be awarded until their workforce was trained in SPC. Unfortunately, some companies just met the minimum requirement of providing basic SPC training and discovered that it's was not good enough.

Both workers and supervisors must understand the essential of the SPC for their own good to prevent losses becoming routine. The management also must have good interpretation on SPC where when workers suggestion is made based on SPC analysis, the management should not neglect their recommendation.

2.2 The Basic Tools for SPC

The seven basic SPC tools are:

- Flowchart
- Pareto chart
- Checksheet
- Cause-and-effect diagram
- Histogram
- Control chart, and
- Scatterplot

However for the purpose of case study, control chart is chosen to be implemented as a SPC tool. Control chart is a broken-line graph illustrates how a process or a point in a process behaves over time. Samples are periodically taken, checked or measured and the results plotted on the chart. The charts can show how the specific measurement changes, how the variation in measurement changes or how the proportion of defective pieces changes over time. Control chart are used to find sources of special-cause variation, to measure the extent of common-cause and to maintain control of a process that is operating effectively.

2.3 SPC Techniques

Essential techniques in SPC include the use of:

1. Process control chart to achieve and maintain statistical control at each phase of the process.
2. Process capability studies that use control chart to access process capability in relation to product specifications and customer demands.