



**Development of Lean Six Sigma and Sustainability  
Model for Product Defect Analysis and Solution : A  
Case Study In Food Processing Industry**

by

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## LIST OF ABBREVIATIONS

CI	Continuous Improvement
SME	Small Medium Enterprise
TPS	Toyota Production System
VA	Value Added
NVA	Non-Value Added
DMAIC	Define, Measure, Analyze, Improve, Control
DMADV	Define, Measure, Analyze, Design, Verify
DFSS	Design For Six Sigma
SPC	Statistical Process Control
5S	Seiri, Seiton, Seiso, Seiketsu, Shitsuke
CTQ	Critical To Quality
VOC	Voice Of Customer
LSS	Lean Six Sigma
LSSS	Lean Six Sigma and Sustainability
DPMO	Defect Per Million Opportunities
TPM	Total Productive Maintenance
TQM	Total Quality Management
SMED	Single Minute Exchange Die
VI	Variability Index
KSS	Kanban-based Scheduling System
SMT	Surface-Mount Technology
SIPOC	Suppliers, Inputs, Process, Outputs, Customers
FMEA	Failure Modes and Effects Analysis
CE	Cause and Effect
OEE	Overall Equipment Effectiveness
MTTR	Mean Time To Repair
EPA	Environmental Protection Agency

## LIST OF SYMBOLS

°C	Degree Celcius
%	Percentage

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**PEMBANGUNAN MODEL LEAN SIX SIGMA DAN  
KELESTARIAN UNTUK ANALISIS DAN PENYELESAIAN  
KECATATAN : KAJIAN KES DALAM INDUSTRI  
PEMROSESAN MAKANAN**

**ABSTRAK**

Disertasi ini membentangkan integrasi elemen-elemen kelestarian, pendekatan Lean dan Six Sigma untuk memacu projek pembaikan berterusan sebagai kajian kes di industri pemprosesan makanan. Pembaikan berterusan (CI) sentiasa dilaksanakan di seluruh dunia menggunakan pendekatan Lean dan Six Sigma dengan mempertimbangkan kelestarian alam sekitar. Walaubagaimanapun elemen kelestarian sosial menunjukkan perkembangan yang tidak meluas, satu fakta yang disokong oleh hasil kajian yang terdiri daripada lebih daripada 40 kertas kerja. Kajian kes ini dirancang untuk menangani jurang dan mengesahkan penambahbaikan pada proses dan elemen-elemen kelestarian menerusi cadangan penyelesaian sambil mengurangkan buangan dalam pengeluaran. Ciri-ciri kecatatan garis hitam dianalisis menggunakan kaedah diskriptif dan visual untuk memahami keadaan semasa. Tujuan projek adalah untuk mengurangkan sekurang-kurangnya 30% hingga 50% kecatatan. Pendekatan Lean Six Sigma telah digunakan untuk mengenal pasti sebab-sebab dan mekanisme yang menyumbang kepada kecatatan garis hitam. Model LSSS telah dibina untuk membimbing kaedah kajian kes ke arah mencapai prestasi proses yang baik dan kelestarian. Reka bentuk penyelesaian telah dibuat dan diuji untuk menilai keberkesanan dalam menyelesaikan isu garis hitam. Hasil selepas penambahbaikan menunjukkan pengurangan kecatatan garis hitam sebanyak 71.4% dan peningkatan kepuasan pekerja di tempat kerja. Dengan ini matlamat untuk projek kajian kes telah dicapai. Oleh kerana tahap Sigma masih pada tahap 4, peningkatan selanjutnya boleh dibuat pada masa akan datang untuk mencapai tahap Sigma yang lebih baik.

**DEVELOPMENT OF LEAN SIX SIGMA AND  
SUSTAINABILITY MODEL FOR PRODUCT DEFECT  
ANALYSIS AND SOLUTION : A CASE STUDY IN FOOD  
PROCESSING INDUSTRY**

**ABSTRACT**

This dissertation presents the integration of sustainability elements, Lean and Six Sigma approaches to drive a continuous improvement project as a case study in food processing industry. Continuous Improvements (CI) have been constantly implemented across the world using Lean and Six Sigma approaches with environmental consideration. However social sustainability element shows insufficient development, a fact which is supported by literature review consisting of more than 40 papers. The case study is planned to address the gap and validate the improvements of process and sustainability elements through solution proposal while minimizing wastes in production. Black line defect characteristics are analyzed using descriptive and visual analysis to understand current condition. The goal is to reduce defects by at least 30% to 50%. Lean Six Sigma approach have been used to identify root causes and mechanisms contributing black line defect. LSSS Model have been constructed to guide case study methods towards achieving good process performance and sustainability. Solution designs have been fabricated and tested to evaluate effectiveness in solving the black line issue. Results of after improvement shows 71.4% reduction in black line defect and improved worker satisfaction at workplace. Goal for case study project have been achieved. Since the Sigma level is still at 4, further improvements can be made in the future to achieve better sigma level.

## CHAPTER 1 : INTRODUCTION

### 1.1 Research Background

In today's fast changing globalization era, manufacturing industries are constantly pushed towards better performance and business excellence with reduced resource consumption and cost. The main factor initiating the change is continuous evolution of technology. It powers the evolving customer base requiring better quality product besides being cost efficient. Contrary to traditional belief, manufacturing does not only involve output anymore, but also includes sustainability elements in terms of economy, environment and social impact. New regulations are being introduced every now and then to protect social and environmental aspects of product or services provided. To keep up with the changing requirements, companies have to quickly react to new market conditions and customer demands. On top of that, organizations have to constantly look for creative solutions and continuous improvements (CI) for both products and processes. CI has already been a part of manufacturing process with practice of quality assurance, process improvement and defect reduction. Further CI implementation methods include Six Sigma and Lean techniques. However, sustainability of CI is always the important and most difficult practice of all in the organization (Janee Ali, Islam, & Poon Howe, 2013).

The challenge for achieving solid operational and performance success is to operate with high efficiency and sustainability. Companies across the globe are under pressure from customers, regulators and other stakeholders to manage their operations in a responsible manner to improve their environmental and social performance

(Cherrafi, Elfezazi, Chiarini, Mokhlis, & Benhida, 2016). To increase efficiency, wasteful actions have to be kept minimal if not possible to be eliminated. By definition, waste is anything that does not add value to the end product and the customer will not be willing to pay for it. In business perspective, removing waste directly translates into reduced cost, given that it is done in a correct way. It is important to strive towards achieving company goals while supporting environmental and social sustainability. Findings in literature indicates the gap in optimizing technical solutions to integrate social and environmental sustainability. As a tool for CI, Lean and Six Sigma may deliver good results, but it is the organizations responsibility to sustain the success form these methodologies. Administration should have a clear focus on giving operators enough empowerment and knowledge so that cleaner production becomes a culture. Continuous improvement activities done in industries are often treated as one time improvement opportunity. As a result, the advantages of solutions are not fully explored as the improvement stops at production floor itself. Changes should be made at systematic level which involves company administration to fully enjoy the improvement advantages.

In order to understand the relationship further, a case study is conducted to study the integration of Six Sigma approach and sustainability in food industry to improve the company performance. Literature review is conducted to identify the conflicts and gaps for realizing the integration of Six Sigma methodology and sustainability particularly in Small Medium Enterprises (SME). Selected SME is a food processing company manufacturing various coffee products and located at Tasek Gelugor in Penang. Further information regarding the company can be found in following section.

## 1.2 Case Study Company and Project Focus

Hang Tuah coffee company or formally name as Syarikat Hang Tuah Sdn. Bhd was founded in 1955 by Tn. Hj. Zainal Bin Hj. Said. Before 1957, brewed coffee were branded as 'Chap 3 Murid' (3 Student Brand). Back then, he was the barrister, and the marketer of the whole bean, ground coffee, and spices. The business was started as a small family based type of company selling Hang Tuah Coffee Powder Mixture. In the beginning, the operation was conducted in a small enterprise, located in Sungai Lokan, Seberang Perai, Pulau Pinang. In 1958 Tuah Store was established. During his tenure, Tn. Hj. Zainal had expanded and grew his Kopi-O business nation wide. On the 20th July 1974, A new facility (P2) was built to replace the old coffee factory in Sungai Lokan as part of the expansion plan. Due to the high demand of Hang Tuah coffee's in the market, this new establishment was built to cater large inventory of raw coffee beans, finished products and marketing office.

After 28 years operating from P2, the demand for this unique coffee, has increased tremendously, requiring Hang Tuah coffee to expand their establishment to support production and storage of products. In 2002, Hang Tuah has again built and moved into its latest facility (P3), located in Taman IKS PERDA, Kubang Menerong, Tasek Gelugor, Pulau Pinang. Aligned with modernization of Malaysia and its technology, Hang Tuah has built the P3 with adopting and synergizing Spanish methodology, technology and machinery. As part of Corporate Social Responsibility (CSR) on becoming environmentally friendly organization, P3 is equipped with a Smoke Control System that control and filter smokes that being produced by this facility by only allowing clean smoke (no black soot or odor) to be released to the

environment. With this move, the surrounding environment the population is not affected by production operation. With its ample space, most of company's Operating Divisions from Logistics, Manufacturing, Production, Human Resource, Research and Development, Quality and Division are based in P3. However, the Sales and Marketing Division is located in Kuala Lumpur.

There are two types of coffee beans being used for coffee production, Robusta and Liberica. Robusta grows out like an umbrella and it grows easily in mild environment. 25-40% of coffee consumed in this world are of Robusta type. Its characteristics of high caffeine content gives it an advantage hence it is used in coffee mixes & instant coffee to give a strong flavor to enhances coffee drinking experience. Liberica coffee grows in small group of plants and it produces large berries. The name itself carries the origin of the coffee, Liberia. Although the amount of Liberica coffee grown throughout the world is much lesser than robusta, it is still largely grown in Western Africa and Malaysia. Liberica have a unique, exceptional taste of ripe berry and sweetness. Below figure shows the coffee processing flow:

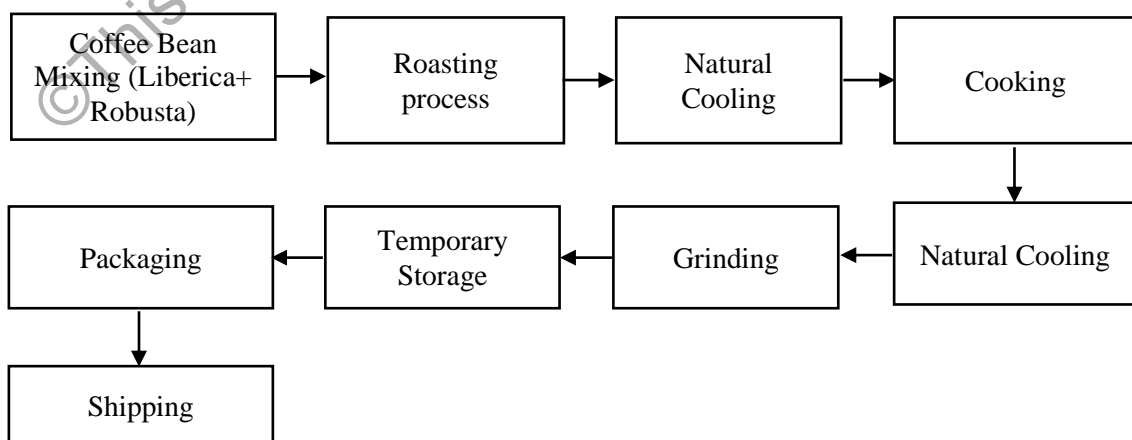


Figure 1.1 : Coffee processing flowchart

Production process of all coffee mixtures requires special care for cleanliness as food and consumer health are closely related. Every equipment and surface that comes in contact with the product are inspected frequently on daily basis to make sure product is not contaminated by hazardous particles, chemicals or foreign objects. Each process has controlled operating environment with specific temperature, humidity and ambience. For instance temperature in packaging area is set at 21.5°C while humidity is set at 32% with good ambience and light illumination in the room.

Cooking is one of the most demanding task on the production floor. Roasted coffee will be mixed with butter and other ingredients with a specific ratio in a cooking pot which is heated by diesel burners. The product of the process is a thick and sticky paste. When experienced operators confirmed that the mixture is thoroughly cooked, it is poured onto a tray table where it will be evenly distributed to be cooled down. The pouring process is facilitated by powered motors which tilts the cooking pot sideways, however the workers still have to distribute the mixture manually using hand tool. As it cools down, the mixture will slowly become less viscous and more solid. Therefore, before next task of rough grinding, workers have to break the cooled down mixture into smaller pieces. The cooking cycle requires tremendous amount of energy from workers. Figure 1.2 shows cooking pot and Figure 1.3 shows one of three cooking work stations. Workers also have to deal with high temperatures during manual operations. They are challenged to perform the job carefully to avoid any quality issues in proceeding processes.



Figure 1.2 : Cooking pot



Figure 1.3 : Cooking station

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One of the challenge faced in roasting and cooking stations is how to maintain low humidity level for coffee beans before grinding. Batches of roasted coffee beans are exposed to open air under carefully controlled environment until it cools down. The natural cooling process usually runs for two weeks. The natural convection by surrounding air is important for maintaining the quality of beans as forced convection may alter the quality and taste of end products. If the convection process is too slow, the hot roasted beans may trap humidity and causing the whole batch to be very sticky and

have inconsistent texture. The whole process is monitored and evaluated by experienced workers. It is why natural cooling process cannot be improved and shortened even though it contributes longer cycle times as it alters the product quality.

The packaging area houses several different types of equipment. Figure 1.4 shows packaging section for coffee sachets. This area has three filter paper packaging machine to fill sachets with coffee powder. It also has a plastic packaging machine complete with conveyor to produce plastic packets which will be filled with 10 coffee sachets by operator. A sealing machine then seals top end of plastic packets. Figure 1.5 shows packaging section for coffee powder packets. The section has two powder filling machines and a worktable with conveyor. Workers picks finished packets and arranges them in box before sealing the box with tape.



Figure 1.4 : Packaging section for coffee sachets



Figure 1.5 : Packaging section for coffee powder packets

The focus for case study is the filter paper packaging machine for coffee sachets. The machine produces two types of product, 1 in 1 and 2 in 1 coffee mixtures, packed in white translucent filter paper. The 1 in 1 product consists of grinded coffee only while sugar is added to coffee for 2 in 1 product. All machines are able to run both products and the products are switched between machines according to production schedule. Figure 1.6 shows one of the filter paper packaging machine. Since the start of plant operation, defects from packaging machines are gradually reduced by implementing different solutions. However the filter paper packaging machines still has high number of defects as the years before.



Figure 1.6 : Filter paper packaging machine

The reject from the machines contribute to 50% of overall product defects. Highest number of defect is for the black line defect as shown in Figure 1.7. This calls for concern as the rejected 50% have to be sent for rework which requires more working hours from operators, more filter paper for repackaging and other resources such as electricity.



Figure 1.7 : Black Line Defect

The production team estimated 10% to 30% increase in monthly overall production cost, including labor cost and overhead costs by almost RM5000 due to the defect. From the estimation, 20% of the increase in cost is contributed by wasted material cost. Electricity cost for machine operation and production area facilities equals to 40%. Labor cost contributes another 40% to the cost increase. The black line defect have been occurring for the past 8 years since the filter paper packaging machine started operation. Even the latest machine acquired 5 years ago produces the same defect. It proves that root cause of the problem is not wear and tear of equipment, instead the machine setup or parameter may have contributed to the defect.

The monthly extra cost of RM5000 due to defect accumulates over 8 years amounts to RM 480000. The estimation hints a huge sum of money can be saved if defects are reduced, highlighting why the project is critical. Therefore facts indicate the need for comprehensive and systematic analysis to solve the problem of high number of defects from packaging area.

### **1.3 Problem Statement**

This dissertation project focuses on Continuous Improvement (CI) project to analyze and solve product defect problem known as 'black line defect', which it causes almost 70% of the overall product rejection rates. Other defects are further discussed in sections later. The focus of this project is on coffee sachet defect where the rejected coffee sachet requires extra time for workers to recycle the coffee powder and thus it results in waste of production time, coffee filter paper and also disrupts the product flow. This study is carried out by analyzing the detail characteristics of defect, identifying root causes and proposing solution. Literature study shows that the application of Lean or Six Sigma approach is very common for quality product case studies and it also offers limited benefits based on their concept and specific methodology. Thus, integration of Lean Six Sigma and considering sustainability elements to drive continuous improvement projects particularly for product quality case studies revealed not only limited studies but also will offer more comprehensive benefits by combining these three approaches (Lean, Six Sigma and sustainability).

## 1.4 Research Question

- How can we best analyse the problem?

The problem is best analysed by combining lean as a smart driver, six sigma as systematic driver and sustainability as a comprehensive driver to consider social, environment and economy. To facilitate improvement process, tools such as Cause and Effect Diagram and 5 Why Analysis are to be used beside direct observation and discussion with personnel involved in machine operation and production

- How can we best solve the problem?

A solution is developed while integrating Lean, Six Sigma and Sustainability components. The solution utilizes six sigma as the foundation of methodology, while lean and sustainability is integrated to every step of process, forming three core entities for improvement project. Fabrication and pilot tests were carried out to validate solution mechanisms.