CHAPTER I
INTRODUCTION

This chapter consists of background, problem formulation, objectives, scopes, and outline of this final project.

1.1 Background

Quality is the ability of product or service in meeting the needs of consumers (Oakland, 2008). Currently, quality is one of the most important factors for consumers in selecting competing products. As the consequence, quality will become the main factor for producers in leading to the success, growth, and competitiveness of business (Montgomery, 2013).

In order to achieve, sustain, and improve the quality of product, the use of technique or activity will be required and it is called quality control. There are several methods that can be applied by producers. One of them is statistical quality control (SQC). According to Besterfield (2008), SQC is the collection, analysis, and interpretation of data used in quality control through statistical approach. There are two major parts of SQC which are statistical process control (SPC) and acceptance sampling. SPC is a statistical tool for monitoring production process to assure that the product resulted by the process will meet the specifications (Qiu, 2013). Sampling plan is a procedure to preserve the quality of outgoing products through quality inspection (Schilling and Neubauer, 2017).

Montgomery (2013) mentioned some classifications of sampling plan such as single-sampling plan, double-sampling plan, and multiple-sampling plan. Single-sampling plan is a procedure in which the decision taken about the quality of a lot of products is only based on a single random sample with size of n. While double- and multiple-sampling plans will need more than one sample to make the decision regarding to the products in the lot. When the lot is rejected, sampling-plan procedures will usually need corrective action. Such sampling procedure is called rectifying inspection where the inspection activity will affect the quality of outgoing product. Others extension of procedures for sampling inspection is determined with Military Standard 105E and Dodge-Romig sampling plans. They presented a set of sampling inspection tables for lot-by-lot inspection.

There are abundance literatures discussing sampling-plan or quality inspection study. Yen et al. (2015) obtained a better performance with a variable repetitive sampling plan based on one-sided process capability indices. Aslam et al. (2013) proposed a variable repetitive sampling plan using Upper Specification Limit (USL) and Lower Specification Limit (LSL) based on process capability index (C_{pk}) as well. Moreover, Aslam et al. (2014) have developed a mixed sampling plan where the attribute and variable plan are combined build upon the process capability index (C_{pk}). Different to Yen et al. (2014) who developed a variable sampling plan based on the Exponentially Weighted Moving Average (EWMA) yield index S_{pk}.

Furthermore, some studies also link sampling-plan with cost. Fink and Margavio (1994) developed economic models that can be used for examining expected profit of different inspection policies, determining additional inspection procedures, deciding the new equipment capital budgeting, and determining the preferred total inspection plan or sampling plan. Moreover, Ferrell and Chhoker (2002) presented a sequence of models to minimize expected total loss that addressed total inspection and single sample sampling, with and without inspector error. Farooq et al. (2017) presented some scenarios to obtain optimal inspection by investigating the relationship between cost savings from each scenario, conformance rates, and external failure costs. Other research of quality inspection from Nezhad and Niaki (2013) and Hsu (2009) are aimed to minimize costs without overlooking consumer or producer risks.

Beside cost, another performance that can be considered by producer is sustainability. Sustainability can be assessed through the resulted environmental impact by the producers. There is possibility to link the quality with sustainability and there have been limited literature that connects quality and sustainability. Kusuma et al. (2015) claimed that carbon footprint for concrete with 8.6 MPa level of strength is 41% higher than concrete with 2.4 MPa level of strength. Nevertheless, Magnier et al. (2016) reported that a sustainable packaging results in a positive perceived quality of products. Generally, literature connecting sustainability and quality are only for the production stage. It is relatively hard to find literature discussing the product's environmental impact in certain inspection plan.

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Figure 1.1 Previous Studies about Sampling Inspection

Figure 1.1 summarizes literature linking cost and quality reviewed in this final project. From the figure, it can be inferred that there is no research trying to link quality, cost, and environmental impact simultaneously in the context of sampling plan design. Nevertheless, from production to the acceptance of product by consumer, there are quality level that must be maintained and possibilities to minimize cost and environmental impact. These possibilities are illustrated in **Figure 1.2**.

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Figure 1.2 Illustration of Product Flow for Sampling Inspection

Production of a lot of products with the size of N incurs cost and environmental impact. The amount of production cost and environmental impact depends on the quantity produced. After being produced, the lot may be inspected using a sampling inspection having sample size n and acceptance number c (c = 0, 1, 2, …). Inspection is done by randomly selecting n items from the lot. The items are inspected and classified as nonconforming and conforming. If the number of nonconforming items are less than or equal to c, the lot will be accepted. Otherwise, it will be rejected. The probability of a lot being accepted P_a depends on the average proportion of defects p resulting from the process, n, and c. Therefore, the probability of rejection is $1-P_a$.

Furthermore, on inspection step, when the lot is accepted, only n items are inspected. Otherwise, when the lot is rejected, total inspection is performed. The total inspection is not always performed. Average total number of items inspected is $n + (N-n)(1-P_a)$. This is known as the Average Total Inspection (ATI). When a lot is accepted, it is shipped to the consumer. However, this lot still has nonconforming items, with the proportion of *p*. When the lot is rejected and total inspection is performed, all nonconforming items found from the lot are replaced with good items. This is called as the internal failure. Then, the lot (it is now free from nonconforming items) is shipped to the consumer. This means that sometimes the consumer gets lot with nonconforming items and sometimes he receives lot that is free from nonconforming items. The fraction of nonconforming items received by the consumer is known as the average outgoing quality (*AOQ*). The maximum value of *AOQ* is called Average Outgoing Quality Limit (*AOQL*). After the consumer receives the lot, he may inspect the lot too. All nonconforming items found by the consumer may be returned to the producer. The producer needs to replace them with good items. To the producer, this is known as the external failure.

Costs and environmental impacts are involved on every step explained above. During inspection, the producer needs to pay for inspection cost and inspection environmental impact. Inspection cost may be resulted from inspector wage, electricity cost (if the inspection is done using tools powered by electricity), or product cost (if the inspection is a destructive test). Environmental impact may be produced by the use of electricity and preparation or production of materials used to perform inspection.

When the lot is accepted, the producer needs to ship it to the consumer. The producer pays shipping cost and the shipment environmental impact. The impact may be resulted by the mode of transportation used by the producer. In the opposite, when the lot is rejected, the producer needs to pay for the replacement cost and replacement environmental impact. To replace a nonconforming item, the cost and environmental impact incurred can be equal to the cost and the environmental impact of producing a new item or reworking. If the consumer finds nonconforming items and returns them to the producer, the producer replaces them with good items. This incurs cost and environmental impact too. Moreover, the producer may also be responsible for the transportation of the returned and replacement items. This incurs additional cost and environmental impact.

It is possible to mathematically construct a model for the above situation. The model can be used to determine optimal sample size n^* and critical number c^* such that total cost and environmental impact are minimized. Thus, the model is a probabilistic model.

However, sampling inspection is not the only option that can be applied to the lot. The producer may also apply no inspection or total inspection. No inspection will only result in external failure cost and external failure environmental impact because after being produced the lot is directly shipped to the consumer. On the other hand, total inspection will result in cost and environmental impact caused by inspection and internal failure.

In this research, total cost and environmental impact from sampling inspection, no inspection, and total inspection are compared. The best option is an option resulting in the lowest total cost and environmental impact. Performing the comparison may not be so complex but determining n^* and c^* for the sampling inspection may need an optimization or heuristic approach. If the application of an optimization approach is not possible, a heuristic approach will be taken. Therefore, there is no guarantee that the provided n^* and c^* are the optimal values.

1.2 Problem Formulation

Based on the background of this final project, it can be inferred that literature simultaneously minimizes total quality cost and environmental impact in the context of lot appraisal is very limited. No previous research attempts to determine sample size and acceptance number of a sampling inspection plan such that the total cost and environmental impact of the system are minimized.

Moreover, no literature simultaneously compares the costs and environmental impacts of sampling inspection, no inspection, and total inspection scenarios.

1.3 Research Objectives

The proposed objectives of this final project are the following:

1. To formulate a mathematical model used to determine optimal or near optimal values for sample size and critical number when sampling inspection is performed.
2. To develop a mathematical used to determine option applied to the lot such that the resulted total cost and environmental impact are at the lowest or near the lowest points. The options are sampling inspection, no inspection, or total inspection.
3. To design a procedure (optimization or heuristic) in order to solve the aforementioned mathematical models.

1.4 Research Scopes

The scopes of this research are:

1. Types of cost considered are inspection cost, internal failure cost, and external failure cost.
2. Environmental impacts considered are the impact resulted by inspection, internal failure, and external failure.
3. Environmental impact considered in the case study of this final project is only carbon dioxide (CO_2) emission.

1.5 Outline of Final Project

The outline of this report is the following:

CHAPTER I INTRODUCTION

This chapter covers background, problem formulation, objectives, scopes, and outline of this final project.

CHAPTER II LITERATURE REVIEW

This chapter covers some theories and literatures relate to quality control with acceptance sampling plan and sustainability concept. These theories are derived from various sources such as books and journals.

CHAPTER III RESEARCH METHODOLOGY

This chapter explains the procedure in carrying out this research and it is also illustrated in a research flowchart.

CHAPTER IV PROPOSED MATHEMATICAL MODELS

This chapter covers the proposed mathematical models, algorithm to find the best option, and verification.

CHAPTER V CASE STUDY

This chapter covers the implementation of proposed procedure into a real data.

CHAPTER VI CONCLUSION

This chapter covers the conclusion and suggestion of this final project.