Cost of quality tradeoffs in manufacturing process

Shivranjan Kumar, Atul Kumar
Mewar University Rajasthan

ABSTRACT
In today’s highly competitive markets manufacturers must provide high quality products to survive. The cost of quality tradeoffs in manufacturing process and inspection strategy selection is examined through a probabilistic cost of quality model explored analytically using a sample set of fundamental inspection strategies (reinspect rejects, reinspect accepts and single inspection) and applied to the case of electric vehicle battery pack assembly. This paper demonstrates that the traditional expected value approach for evaluating cost of quality implications of manufacturing and inspection is often misleading. Decision tree formulations and discrete event simulations indicate that cost of quality distributions is asymmetric. High internal- and external failure costs, manufacturing process non-conformance rates and inspection method error rates are contributing factors. The alternative metric of expected utility captures decision makers risk aversion to high cost outliers and changes the criteria for optimality and favors inspection strategies and manufacturing processes that minimize external failure events with increasing risk intolerance.

I. INTRODUCTION
In manufacturing industries, the general term “quality” refers to what quality management literature divides into the two complementary categories of quality of design and quality of conformance. Whereas quality of design focuses on how the product design meets consumer requirements, quality of conformance is concerned with whether the quality produced and provided to the consumer meets the intended design. Both quality levers act jointly to determine the quality perceived by the consumer etc. For a fixed choice of manufacturing process, the key lever controlling the subsequent outgoing quality of conformance is inspection.[1] The goal of inspection is to identify produced defects before they are delivered to the customer. Even within inspection itself, a wide range of strategy alternatives are available.

Where many different paths towards the goal of achieving high quality exist, finding the most efficient and cost effective one can be a difficult task for manufacturers. [2] Especially in multistage manufacturing systems

II. METHODOLOGY: COQ FRAMEWORK

To compare inspection strategies for a fixed choice of manufacturing process, the P-A-F cost of quality elements that must be considered are appraisal, internal failure and external failure costs. These elements are directly affected by the choice of inspection strategy and can be used for inspection strategy comparison. More specifically, the metric we will be using for inspection strategy comparison when the manufacturing process is fixed includes the sum of all three cost of quality elements defined as the cost beyond perfect manufacturing (CBPM)

Cost distribution approach
For any given inspection strategy, a produced item can follow one of many possible paths where a path is defined as a unique sequence of produced or reworked quality of conformance occurrences and inspection decisions that end in one of three possible events; delivered to the customer and conforming, scrapped, delivered and non-conforming.[4]

Each path mentioned in A has an associated cimi outcome that depends on the specific number of occurrences of each available inspection method, number of rework attempts as well as final outcome event.

For a given inspection strategy, any path with its resulting cimi outcome has a probability of occurrence that depends on the specific number of occurrences of each available inspection method, number of rework attempts as well as final outcome event.

For a given inspection strategy, any path with its resulting cimi outcome has a probability of occurrence which is its own function of manufacturing non-conformance rate and inspection error rates. [5]

III. SINGLE INSPECTION
In the single inspection strategy, declaring a produced item to be of conforming quality leads to delivery to the customer whereas a declaration of non-conformance leads to rework followed by reinspection if within the rework limit, l; scrapping if the limit is reached. One can
make the distinction between three broad subsets of possible cost outcomes;

![Figure 1](image1.png)

Cost outcomes of conforming items delivered to the customer (∈ \( \mathbb{C}^* \)), cost outcomes of items failing internally (∈ \( \mathbb{C}_A \)), and cost outcomes of non-conforming items failing externally after delivery (∈ \( \mathbb{C}_B \)). Although these three subsets exist regardless of the rework limit \( l \), the number of unique cost outcomes within each subset is a function of \( l \) and specific to the inspection strategy being modeled. [6]

**Process Based Cost Model (PBCM)**

However, in real world assembly systems such as the battery pack assembly line, the welding processes and inspection stations have a fixed cost component that must be considered. This fixed cost component is a function of welding process non-conformance rate, inspection error rates as well as the specific choice of inspection strategy since all of these factors influence required capacity of the production equipment and thus the required investments. [7] An additional complication stems from the fact that because the number of manufacturing process runs required to achieve a specified number of conforming delivered items is itself a function of welding process non-conformance rate and inspection error rates, all assembly processes’ direct labor and fixed cost allocations are affected [8]

![Figure 2](image2.png)

Figure 2

**IV. CONCLUSIONS**

In this thesis, a cost of quality approach is implemented to reconcile manufacturers’ competing objectives of cost minimization and quality of conformance maximization in inspection strategy selection. From a cost of quality perspective, each inspection strategy has its own balance of inspection, internal- and external failure costs driven by the imperfect nature of manufacturing processes and inspection methods.

To make a well informed inspection strategy selection a decision maker must understand the tradeoffs between these elements of cost of quality. The first metric developed and implemented in this thesis for inspection strategy and manufacturing process selection is the expected cost of imperfect manufacturing and inspection per unit.

**REFERENCES**