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# Optimization of quality costs

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**Abstract**

The main goals of quality management in all industries are customer satisfaction by delivery of defect-free products and the radical reduction of defect rates and quality costs in the production. Controlled technological processes are the most important way to reach these goals. These principles are standard in mechanical engineering and are in use with great success. The properties in electronics production are different from the properties in mechanical engineering. During the assembly of electronic devices, processes are sensitive to the influences (environmental, parameter variation, etc.), that act on these processes. These influences are very strong, especially in the production of small batches of assemblies and a high mix of products. Processes can become uncontrolled, the defect rates can rise, and it is necessary to have inspection and repair processes after the different technological processes. But what about the quality costs? Is it sensible to do these quality control steps from the economical point of view? What is the right inspection strategy—no inspection or 100% inspection or statistical process control? To answer these questions new simple and powerful quality cost models have been developed at the Electronics Technology Laboratory and are in use in electronic producing industries. The quality costs are the "measurement system" to compare different inspection strategies with each other. The costs are calculated by the use of mathematical models—the quality cost models. To analyze and optimize the quality processes of a complete production line we use the method "Dynamic Programming", developed by the American scientist, Bellman in the early 1950s of the 20th century.


## 1. Introduction

Controlled technological processes are the most important way to reach a high quality level in mechanical engineering industries. Statistical process control (SPC) and Failure Mode Effect Analysis (FMEA) are other ways to reach this goal. It is possible to use these methods also in electronics production in the case of producing batches with a high number of similar PCBs. But in a production process with many different products and small batch sizes, there are relatively high defect rates and some technological processes may be uncontrolled. The objective of this paper is to show new models to decrease the quality costs of such technological processes.

## 2. The basic quality cost model

At first we look at a chain of technological processes—for instance, a SMT production line as in Fig. 1. The SMT line consists of a PCB transport system, a solder paste printer, a chip shooter, a pick-and-place machine, a reflow oven and an inspection system at the end. In our example the process of solder paste printing should not be well controlled. Consequently, there are some poorly printed PCBs. These PCBs are represented by the defect rate $p$.

What can we do with this uncontrolled process? We insert a test and a repair process in the line after this uncontrolled technological process. This is shown in Fig. 1. This picture shows the abstraction of the processes also: $T$ signs a technological process and $Q$ signs a quality process. A quality process consists of an inspection and a repair process.

But is it sensible to do this in the context of quality costs? To find the answer we use quality cost models. The basic model is described in this chapter. Fig. 2

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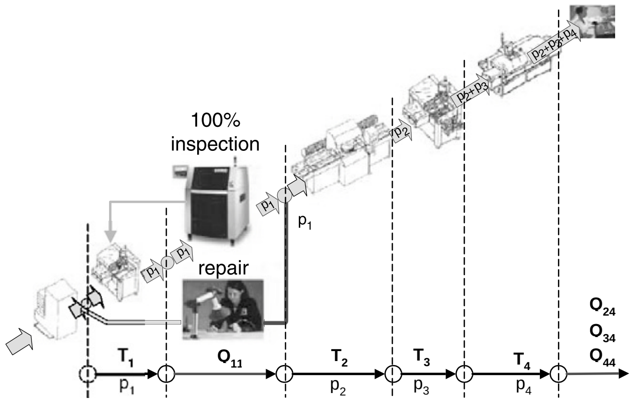


Fig. 1. SMT line with inspection and repair process and abstraction of the processes.

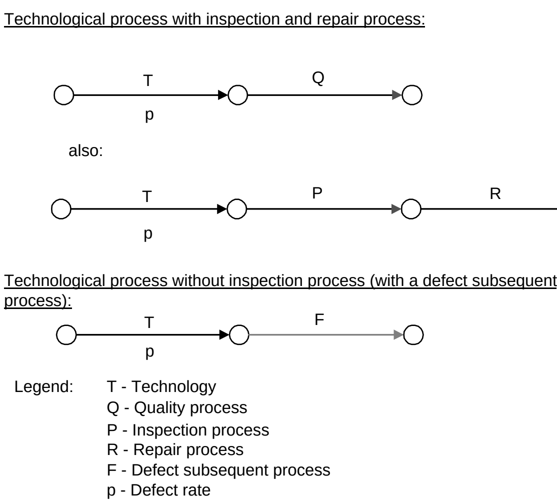


Fig. 2. Abstraction for one technological process.

shows the abstraction of one technological process with and without a quality process.

The technological process $T$ in Fig. 2 has a defect rate $p$. In the first case a quality process $Q$ (consisting of the inspection process $P$ with 100% inspection of the PCBs and the repair process $R$) is added to detect and to eliminate these defects. The inspection and repair processes cause quality costs. In the second case there is no quality process to detect and to remove the defects after the technological process. But there is also a defect rate $p \neq 0$ and the defects will be processed. It means the defects also cause quality costs, but later in the technological line (latest in the final inspection process). With the view to these quality costs we say there is a virtual process called defect subsequent process $F$. And now we can answer the question: Which case is cheaper—with or without a quality process right after the technological process? To answer this question we have to make the following assumptions: all of the produced PCBs are inspected (100% test), all PCBs with defects are identified and repaired, after the last technological process in the line there is a 100% test of the PCBs (for example, an ICT) and the quality costs are calculated as costs per unit (for example, per PCB).

To describe the quality costs of the above discussed two cases the following equations are used:

Costs without an inspection after $T$:

$$k_0 = k_T + pk_F. \tag{1}$$

Costs with an inspection after $T$:

$$k_1 = k_T + k_P + pk_R \tag{2}$$

with: $k_T$ is the costs of the technological process $T$ per part, $k_F$ the defect subsequent costs per part, $k_P$ the inspection costs per part, $k_R$ the repair costs per part, $p$ the defect rate of $T$.

Of course the technological costs $k_T$ are the same with and without the quality process $Q$ and so they are not a necessary part of the calculation. If the defect subsequent costs $k_F$ are higher than the sum of inspection and repair costs $(k_P + k_R)$, a point of intersection of the two lines (the graphs of the Eqs. (1) and (2)) exists. This point (the so-called break even point) is described by a defect rate $p^*$ and the costs $k^*$. The equation of $p^*$ is:

$$p^* = \frac{k_P}{k_F - k_R}$$

$$\text{with} \quad \begin{matrix} k_0 = k_1 = k^* \\ p = p^* \end{matrix} \quad \text{if } k_F > k_P + k_R. \tag{3}$$

For low values of $p$ (see Fig. 3—left from $p^*$), the use of a quality process $Q$ at this time is more expensive than to expect the PCBs later on during the final inspection. With this simple model it is possible to design a technological chain (with technological and quality processes) dependent on the defect rate $p$, if the quality costs are known.

The extensions of this quality cost model for more than one technological process and for the influences of the inspection processes are shown in [1].

But what is the disadvantage of this model? It is a static quality cost model. To use this model it is necessary to have quality data of the considered product over a long period of time. With these data it is possible to calculate the costs and to create an inspection strategy. This model is not usable for new products, because of missing quality data. In this case the only

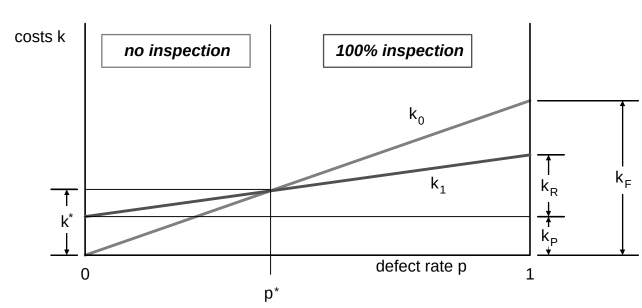


Fig. 3. Costs with and without the quality process.