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Assessing acceptance sampling application in manufacturing electrical and electronic products

B.M. Deros*, C.Y. Peng, M.N. Ab Rahman, A.R. Ismail, A.B. Sulong
Department of Mechanical and Materials Engineering, Faculty of Engineering, Universiti Kebangsaan Malaysia,Bangi 43600, Selangor, Malaysia
* Corresponding author: E-mail address: hjbaba@eng.ukm.my

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ABSTRACT

Purpose: This paper discusses the use of acceptance sampling technique as a practical tool for quality assurance applications to decide whether the lot is to be accepted or rejected.
Design/methodology/approach: In Malaysia, single attribute acceptance sampling plan is widely practiced for quality assurance purposes in manufacturing companies. Literature showed that majority of past studies on acceptance sampling had focused on the development and establishment of new methods for acceptance-sampling application. However, there is none that had investigated the relationship between acceptance sampling plan selection and effectiveness of the selection. Therefore, in this study, the authors had analyzed the effectiveness the acceptance sampling plan application method and its implementation problems in manufacturing electrical and electronics products. The study was conducted by using case study methodology at three manufacturing companies' coded names: company A, B and C. In this paper, the authors would like to share the case study companies' experienced of acceptance sampling plan selection and difficulties that they had faced during the course of implementing acceptance sampling in their production lines.
Findings: The result from the three case study companies showed by implementing acceptance sampling they could easily investigate and diagnose their suppliers' product quality immediately upon their arrival at the company premise.
Practical implications: The continuous improvement and review of acceptance sampling plan is important to improve the products quality and ensure continuous customer satisfaction.
Originality/value: All the three case study companies agreed that acceptance sampling implementation had improved their product's quality in the market place.
Keywords: Acceptance sampling plan;Implementation; Quality assurance; Effectiveness

1. Introduction

Sampling plans are hypothesis tests of the product that has been submitted for an appraisal and subsequently resulted with acceptance or rejection [29]. A sample is selected and checked for various characteristics. The product may be grouped into lots or may be a single piece from a continuous operation. For products grouped into lots, the entire lot is accepted or rejected. The decision is based on the specified criteria and the amount of defect or defective units found in the sample. Sampling at the end of manufacturing process provides a confirmation on the

adequacy of the quality control procedures in a manufacturing department. If the process has been controlled satisfactorily, the product would be accepted and passed to the customer. If the process or quality controls have broken down, the sampling procedures will prevent defective products from going any further or leakage to the customer. The manufacturing department, as part of the process or quality control program uses sampling techniques for quality monitoring purposes [3]. Effective acceptance sampling involves effective selection of the products and the application of specific rules for lot inspection that follows the standards. The acceptance-sampling plan applied on a lot-by-lot basis becomes an element in the overall approach to maximize the quality level at minimum cost [25].

2. Literature review

Acceptance sampling had become an important field of statistical quality control was popularized by Dodge and Romig [25]. The U.S. military to the testing of bullets during World War II originally applied this sampling technique. If every bullet were tested in advance, no bullets would be left to ship. On the other hand, if none were tested, malfunctions might occur in the battlefield with potentially disastrous results [17]. Dodge reasoned that a sample should be picked at random from the lot based on the basis of information that was yielded by the sample [25]. A decision should be made regarding the disposition of the lot. In general, the decision is either to accept or reject the lot. This process is called Lot Acceptance Sampling or Acceptance Sampling [18]. There are two major classifications of acceptance plans: attributes ("go, no-go") and by variables [24]. The attribute type is the most commonly used for acceptance sampling [19]. Attribute inspection is done based on physical characteristics such as appearance, colour, feel and taste. It results in classification of products into categories such as good/bad, bright/dark, tight/loose, smooth/rough and so on [14]. In measurement inspection, a characteristic is measured by using an instrument. The sampling plans for attribute inspection will specify the number of defectives that can be tolerated in a sample of specified size to accept lots [10]. The sampling plans for variables usually require calculation of an average, range or standard deviation before deciding to accept or reject a lot. Thus, implementation of sampling by variable is rather complicated and may require specially trained personnel. However, variable sampling plan are more efficient in the sense that they require less sampling compared to attribute plans [14].

2.1. Sampling plan categories

According to Schilling [25], acceptance sampling plan falls into five categories: single, double, multiple, sequential and skip lot sampling plans. Single sampling plan happens when one sample of items is selected at random from a lot and the disposition of the lot is determined from the resulting information. These plans are usually denoted as (n, c) plans for a sample size n, where the lot is rejected if there are more than c defectives. These are the most common and easiest plans to use, even though it is not the most efficient in terms of average number of samples needed. Double sampling plan happens after the first sample is tested, there are three possibilities: accept the lot; reject the lot and no decision. If the outcome is no decision, and a second sample is taken, the procedure is to combine the results of both samples and make a final decision based on that information. Multiple sampling plans are extension of the double sampling plan where more than two samples are needed to reach a conclusion. The advantage of multiple sampling is smaller sample sizes. Sequential sampling plans is the ultimate extension of multiple sampling where items are selected from a lot one at a time and after inspection of each item a decision is made to accept or reject the lot or select another unit. Skip lot sampling plan means that only a fraction of the submitted lots are inspected. Making the final choice between single or multiple sampling plan that has acceptable properties is a matter of deciding whether the average sampling savings gained by the various multiple sampling plans justify the additional complexity of these plans [22]. According to Taylor [27], one should follow this approach if you are uncertain of not knowing how much sampling, inspection will be conducted on a day-by-day basis.

2.2. Previous studies on acceptance sampling

Acceptance sampling could help to improve system reliability by improving component reliability through more stringent acceptance sampling plan selection [9]. Specifying a prior distribution on the number of defects in a lot, and revising the distribution based on information in the acceptance sample do this. Then, transform a given system on the number of defects in the posterior distribution into a reliability distribution. There were several researches conducted regarding acceptance sampling. The critical review for past researches of application of acceptance sampling in the manufacturing industry is summarized in Table 1.

As a summary, it was found that past studies did not investigate the relationship between acceptance sampling selection and their effectiveness. Selecting the correct types of acceptance sampling level is very important prior to the start of any inspection. The wrong selection will cause the leakage of failed products to customers and increase the products failure risks, thus rework costs incurred for screening the products. Therefore, in the authors' opinion it is a necessity to conduct a research on the application of acceptance sampling in Malaysian electrical and electronics products manufacturing industries. This is to ensure the electrical and electronics products passed or marketed to the customers are assured in terms of their quality and reliability.

3. Research methodology

Case study methodology was used in this research. It involves an in-depth investigation and appropriate when trying to answer the 'how' and 'why' questions of research [33]. Case study evidence may be in the form of qualitative (e.g. words), quantitative (e.g. numbers) data or both, the combination of both data types is believed to be highly synergistic. This is in-line with the main research objective, that is to answer some of the 'how' and 'why' questions in acceptance sampling implementation. In

Table 1.
Critical reviews of previous acceptance sampling studies

No.	Researcher	Research Topic
1.	Wu and Pearn, 2007	Process reliability index, Cpk sampling
2.	Gonzalez and Palomo, 2003	Bayesian sampling follows to Poison distribution
3.	Baker et al. 1996	Bayesian attribute sampling comparison of statistical and classical confidence levels of data
4.	Kwon, 1996	Improve the test duration of Bayesian sampling plan
5.	Kaya and Engin, 2007	Genetic algorithms sampling in multi-stage process
6.	Cheng and Chen, 2007	Genetic algorithms in design of attribute double sampling
7.	Sohn and Jang, 2001	Degradation sampling with fitted model
8.	George, 1994	Sampling application for exported products from overseas supplier
9.	Pearn and Wu, 2006	Process capability indices (PCI) sampling
10.	Klaassen and Chris, 2001	Credit based acceptance (CBA) sampling
11.	Balasooriya et al., 2000	Weibull distribution with asymptotic distribution theory sampling for reliability
12.	Legan et al., 2001	Microorganisms concentration controlled by attributes sampling
13.	Pendrill, 2006	Comparison of sampling by variables and attributes
14.	Borget et al., 2006	Control of chemotherapeutic batches in an hospital pharmacy
15.	Kobilinsky and Bertheau, 2005	Grain control with application to genetically modified organism (GMO) detection

this study, the main aim of case study methodology was to extract detailed information about how and why a production line for manufacturing electrical and electronics products had used the acceptance sampling technique. Conducting structured interviews on the company's production engineers and managers using a set of questionnaire-collected data. Case study research relies on multiple sources of evidence. The six sources of evidence most commonly used in case study research are: documents; archival records; observations; physical artifacts; focused interviews and open-ended interviews. The researcher must be able to use these different sources of evidence in a converging manner by defining the 'facts' of the case and to get such convergent, the researcher must ask the same questions on 'multiple sources of evidence' [33]. The case study questionnaire was designed in a way to provide details response and feedback from the industries as needed for data collection and improvements to the product quality. The questionnaires include information about the acceptance sampling plan selection, production process failure, difficulty of the acceptance sampling plan and suggestions (open ended questionnaires). The questionnaire design was based on the steps and procedures adapted from William [31]. A successful questionnaire requires careful planning, methodological application, and detailed analysis of the results. The questionnaire's basic objective is to determine the company's performance (doing right or wrong), determine the areas of improvement, benchmark with other competitors, and how to serve the customer better [4]. The well-known phrase GIGO (garbage in, garbage out) is considered as one of the measuring tools, as it has more accurate questionnaire design. The questionnaire design is part of the important stage in the process to get the best results and analysis. The research process is listed as follows: designing the structured interviews questionnaire; interviewing production engineers and managers; conduct plant tours to verify collected data, questions and understand the production line operations, and finally, analyze the results obtained.

4. Results and discussions

The case study structured interview questionnaires were administrated at three large foreign multinational companies with more than 1,500 employees. They are code named, Company A, Company B and Company C. The case study structured interview questionnaires consists of three parts: first, the company background information; second, studying and analyzing the company's application of acceptance sampling; and finally, reviewing the effectiveness and benefits of acceptance sampling application. All the three selected case study companies are located in the state of Selangor, Malaysia. For the past 20 years, they were involved in manufacturing electrical and electronics products in Malaysia. All the three companies' have similar backgrounds in terms of products they produced and the manufacturing processes used. Therefore, the authors had chosen these three companies as the benchmark companies for acceptance sampling adoption and implementation in Malaysian companies. The case study was carried out using verbal interview with the engineer and manager of each company. On overall, all the three companies had adopted and implemented acceptance sampling in their inspection process. The summary of each case study company background is as shown in Table 2.

Table 2.
Summary of Case Study Companies Background

Company	Company Type	Products Manufactured	Acceptance Sampling
A	Japanese	Disk drives, DVD camera	Yes
B	European	Heat ventilation products	Yes
C	Japanese	Audio products, camcorders	Yes

All the three companies had adopted the application of acceptance sampling plan with Military Standard 105E attribute single sampling plan for both incoming and outgoing inspection as shown in Table 3.

Table 3.
AQL inspection level for the case study companies

Acceptance Sampling	Company A	Company B	Company C
AQL Level Normal Tighten Loosen	Incoming AQL Level II 0.4% 0.1% 1.0%	Incoming AQL Level II 0.6% 0.4% 1.0%	Incoming AQL Level II 0.4% 0.1% 1.0%
AQL Level Normal Tighten Loosen	Incoming AQL Level II 0.4% 0.1% 1.0%	Incoming AQL Level II 0.6% 0.4% 1.0%	Incoming AQL Level II 0.4% 0.1% 1.0%
AQL Level Normal Tighten Loosen	Incoming AQL Level II 0.4% 0.1% 1.0%	Incoming AQL Level II 0.6% 0.4% 1.0%	Incoming AQL Level II 0.4% 0.1% 1.0%
Review Frequency	Yearly	Yearly	Yearly

There are two types of data used for comparisons:

(a) Incoming inspection: incoming inspection results (Acceptance sampling plan);

(b) Production result: production process 100% inspection results

(Leakage of failure detection by incoming inspection)

COMPANY A

There are two major categories of products: electrical parts and mechanical parts. The defect classification follows to Military Standard 105E: major, minor and critical. Judgment major is given when the item cause failure or did not function as intended. Judgment minor is given when the item lower or impaired the efficiency, shortened the useful lifetime or reduce the value of the item. Judgment critical is given when the item result in hazardous or unsafe conditions for individuals using or maintaining the product. Each type of defects is assigned with acceptable sampling plan as final products judgment.

The review on the effectiveness of acceptable sampling plan to detect supplier's products defect failure is conducted by data collection from previous month inspection result. Figure 1 and Figure 2 shows the comparison of electrical and mechanical parts inspection result and production rejection results (after incoming inspection).

The analysis found that sampling inspection plan of this company is insufficient to detect the parts failure delivered from supplier. The incoming inspection was observed to be under control at AQL 0.15%. However, the production rejection failure was found not achieving the target at AQL 0.15%. The weak point of the parts failure leakage was identified in Table 4. From the verbal interview, the authors' conclude that the respondent was unsatisfied with the current production rejection failure result.

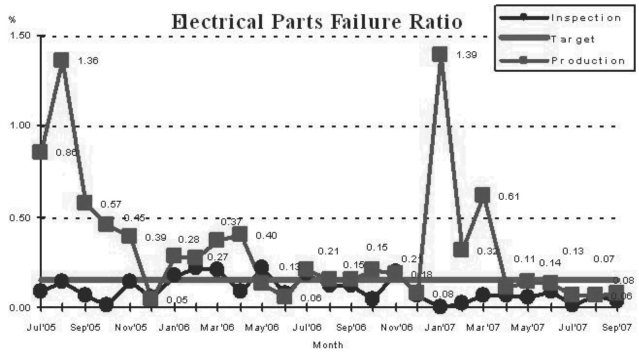

Fig. 1. Electrical parts inspection result and production rejection result (after incoming inspection) comparison data at Company A

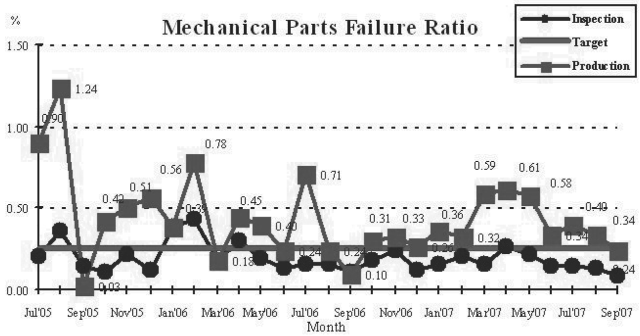

Fig. 2. Mechanical parts inspection result and production rejection result (after incoming inspection) comparison data at Company A

Table 4.
Reasons of parts failure in incoming and production

	Incoming Inspection	Production Rejection
Electrical parts	Suppliers have transferred the production process to sub-contractors	New models with problems
Mechanical parts	Parts higher precision hard to control	Low quality parts purchased from China

COMPANY B

All the parts purchased from suppliers are mechanical or semi-finished assembly products. Additional sample size code (e.g. C, D, E etc.) will be assigned to the products in order to find the applicable code letter for inspection in the particular lot or batch size. Sample size code is selected based on the mechanical precision requirement for each product. Higher precision of parts will require more quantities to be inspected. For visual inspection, the visual standard is based on the limit sample, which is a unit of product showing the worst condition for it to be acceptable. If the product appearance inspection is found worst than the limit sample, the judgment of this product is rejected. The limit sample must be agreed in between suppliers and customers for standard judgments. The limit sample needs to have validity date and both

parties' endorsement on the sample. For equipment measurement inspection, the parts are measured with a standard gage and some are coupled with specially made gage for fixture confirmation. To maintain the equipment and fixture precision, re-calibration for equipment and fixture need to be conducted by following to the preventive maintenance scheduling.

Figure 3 shows the comparison of parts inspection result and production rejection results (after incoming inspection). On overall, it was found that the production has higher rejection, compared to incoming sampling inspection.

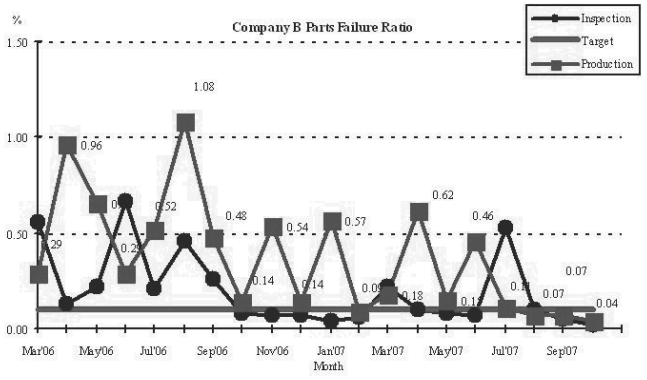

Fig. 3. Company B parts inspection result and production rejection result (after incoming inspection) data

The production rejection failure did not achieve the target percentage, i.e. AQL 0.10%. From the verbal interview, the respondent explained that this company was unsatisfied with the current production rejection failure result. Currently, the heat ventilation products are unstable in term of quality performance. In total, there are three suppliers of these products. All the parts suppliers are sourcing them from China. These parts are purchased at very low prices. As the results, Company C found the qualities of the parts supplied from China are at lower quality level if compared to the parts purchased locally in Malaysia.

COMPANY C

There are two main categories of parts – mechanical and electrical. Each part has various types of testing and inspection methods. In this case study research, audio products has been chosen for analysis because this product had applied acceptance sampling plan for inspection in the company. For this product, the acceptance sampling level is set at AQL 0.4%. This product is tested with visual inspection, measurement, fitting, mechanical tape test and electrical inspection test.

Comparison of parts inspection results and production rejection results (after incoming inspection) were collected and shown in Figure 4. Overall, it was found that the production line had slightly higher rejection, compared to incoming sampling inspection.

From the interview, the respondent explained that Company C was unsatisfied with the current production rejection failure result. The respondent explains that their audio products were inspected with electrical automated machine. The electrical automated machine is unable to cover all the functional failure on the integrated circuit. The selection of printed circuit board detection points to be inspected in the automated machine is based on the previous products failure history. For example, the new model's integrated circuit has total 200 inspection points, which needed to be inspected. However to reduce the inspection duration and cost, these products are required to inspect only 50 points. The decision of this 50 points to be inspected are based on the history of previous failure occurred in the production and the responsible risk of failure. Additional inspection points will be later added in future from time to time, if there is any failure occurred in the production.

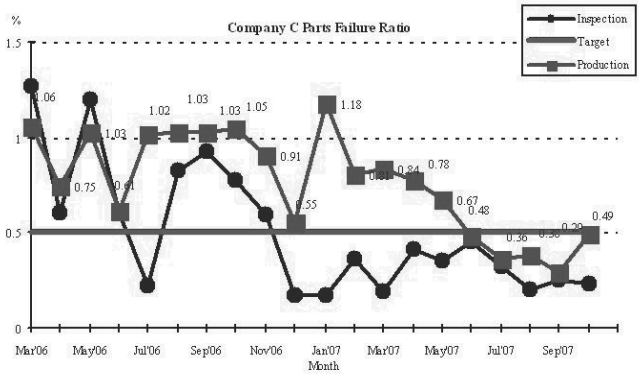

Fig. 4. Company C parts inspection result and production rejection result (after incoming inspection) comparison data

All the three companies agreed that the application of acceptance sampling could improve the productivity and quality of their products. Figure 5 shows the perception of the engineers and managers at the three case study companies for acceptance sampling implementation in their company.

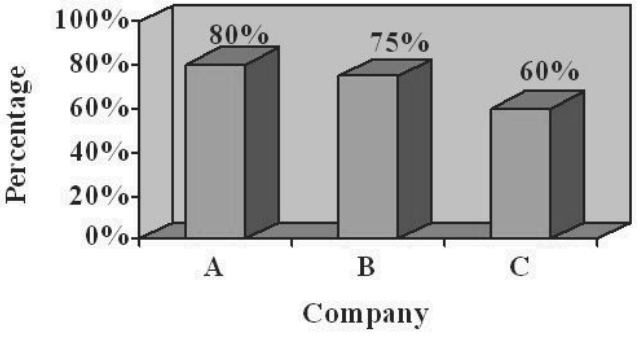

Fig. 5. Case study companies' perception of acceptance sampling implementation

From the interviews, the authors found each company had spent considerable amount of cost and time to develop and implement the acceptance-sampling plan. The inspection costs include manpower cost and equipment purchased for inspection and improved the factory facilities. All the respondents believed the money and time spent are worthwhile with the results they obtained through acceptance sampling. The results of improvements through acceptance sampling implementation are faster delivery (follow to just-in-time, JIT standard), better

quality, lower products cost and higher reputation for company's products. From the interviews with the plant personnel, it is understood that the application of just-in-time (JIT) activities is no longer applied only to Japanese companies but also to European company. For further improvement of the company's productivity and deliveries, the European company had also benchmark and learned from Japanese company on how to apply and implement the JIT activities. The European company had started to apply all others relevant acceptance sampling activities which could further improve their effectiveness and efficiency of their production lines. In this regards, there are few suggestions and feedbacks from the respondents to improve the acceptance sampling application. The respondents of the interviewed companies suggested the company's top management should regularly review and improve supplier parts detection through:

a. Conduct tightened inspection continuously for all new parts for the first 5 lots of delivered from the supplier;
b. Conduct on-site inspection to suppliers' plant for checking process capability and consistency confirmation, and thus conduct necessary improvement activity immediately;
c. Review the current acceptance sampling plan regularly; and
d. Review the inspection methods (electrical, measurement or visual inspection) regularly. Add the inspection methods (if necessary) to improve the detection process.

5. Conclusions

Effective acceptance sampling involves effective selection and the application of specific rules for lot inspection. The acceptance- sampling plan applied on a lot-by-lot basis becomes an element in the overall approach to maximize quality at minimum cost. Since different sampling plans may be statistically valid at different times during the life of a process, therefore all sampling plans should be periodically reviewed. From the case study, it was found that the companies have clear vision of their strengths, weaknesses, opportunities and threats analysis. The three case study companies' have performed assessment on their acceptance-sampling plan and relates its effectiveness to the achievement on their products quality. The continuous improvement and review of acceptance sampling plan is important to improve the products quality and ensure continuous customer satisfaction.

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