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PRODUCT QUALITY INSPECTION IMPROVEMENT BY ATTRIBUTE ACCEPTANCE SINGLE SAMPLING PLAN AND ITS COMPUTER PROGRAM APPLICATION

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ABSTRACT

High competitive market nowadays forces business organizations to compete based on best quality to enhance their competitive advantages in the world market. Inspections of in-coming raw material, manufacturing processes and finished goods become significance to prevent defects which impacts product quality. However, 100% inspection can cause unnecessary time, manpower, machine as well as increase workers' exhaustion and higher inspection cost. This research has an objective to improve an inspection process at an example automotive part factory from 100% inspection to an attribute acceptance single sampling plan. The proposed sampling plan should yield minimum consumer risk with minimum quality inspection cost. A computer application is designed to eliminate repetitive calculations and to support an implementation stage. The research methodology consists of a quality inspection data gathering, a suitable sampling plan selection, a quality cost calculation, a computer software generation, a sampling plan implementation and validation. The result shows a 52.25% quality cost reduction per lot and a 97.65% inspection time reduction per lot. Furthermore, the single sampling plan yields minimum producer's risk with α = 10.54% and minimum consumer's risk with β = 5.41%. The computer program application is validated with user's satisfaction survey. The result shows impressive user satisfaction according to shorter calculation time with 100% precision.

Keyword: Single Sampling Plan, Product Quality Inspection, Quality Improvement

INTRODUCTION

To succeed in a global market nowadays, business organizations are competing with cost, time and quality. Inspections of incoming raw materials, work in process and final products aim to detect defects and prevent them from slipping through manufacturing processes. Several inspection plans have proved their significance and effectiveness. Acceptance sampling is the technique used to verify that products adhere to quality standard. Acceptance sampling inspection can range from 100% to a few items from lot. Even 100% inspection assures zero defects, it causes a high inspection cost, employee's boredom and fatigue from repetitive work. This research is a case study at one of automotive part manufacturers where problems occur according to high inspection cost from 100% inspection. With excellent quality record of zero defects, the quality assurance department looks for possibility in replacing 100% inspection with a sampling plan. The proposed sampling plan must have a customer's approval with minimum consumer's risk and yield minimum producer's risk. This research aims to set up a sampling plan with minimum inspection cost to replace 100% inspection. Moreover, a development of a computer program application by using Visual Basic language helps the inspection team define the most suitable sampling plan parameters (n, c) to reduce repetitive manual calculation and minimize calculation errors.

LITERATURE REVIEWS: ACCEPTANCE SAMPLING PLAN

Fundamentals of Acceptance Sampling

Acceptance sampling can be defined as a statistical process control (SPC) technique used to help make decision to accept or reject lot. Acceptance sampling inspection can occur at the beginning of the process when receiving incoming raw materials, between the process as in the case of work-in-process or at the final inspection. There are different methods to develop sampling plans.

Producer's and Consumer's Risk

Producer's risk is the risk associated with rejecting a lot of materials that has good quality. Producer's risk is denoted by alpha (α) and is referred to as a Type I error. Consumer's risk is the opposite with accepting a bad lot of materials. Consumer's risk is denoted by beta (β) and is called a Type II error. Table 1 shows contrast between alpha and beta risk. Good acceptance sampling plan should reduce producer's risk to low levels, at the same time, maintaining consumer's risk at acceptable levels. (Foster, 2001)

Table 1 Alpha and Beta Risk

	State of Nature	
	Product is Good	Product is Defective
Consumer accepts product	OK	Consumer's risk (β)
Consumer rejects product	Producer's risk (α)	OK

Acceptable Quality Level and Lot Tolerance Percent Defective

The acceptable quality level (AQL) is the maximum percentage or proportion of nonconforming items in a lot that satisfies a process average. It is associated with producer's risk. Lot tolerance percent defective (LTPD) is the level of poor quality that is in a lot. It relates to consumer's risk. Generally, it is a management decision to assign values of AQL, LTPD, producer's risk (α) and consumer's risk (β).

n and c

After an assignment of AQL, LTPD, Producer's risk (α) and Consumer's risk (β), n and c can be determined which set a sampling plan as well. Acceptance sampling plans are designed to give values of n and c, where:

n = the sample size of a particular sampling plan
c = an acceptance number (if defects are higher than c, it causes lot rejection)

OC Curve

The operating characteristic (OC) curve gives an assessment of the probabilities of acceptance for a lot. This curve can be used to develop sampling plans. When c gets smaller, the OC curve gets steeper. This means that higher values of c lead to higher probabilities of accepting bad lot (consumer's risk). Higher values of n result in the OC curves that show greater confidence in accepting a good lot. There are two ways to construct OC curves. The first uses the binomial distribution and the second, the Poisson distribution. Using a sample size n and average percent defective p, OC curves can be developed by using a Poisson approximation of a binomial distribution. (Grant and Leavenworth, 1999; Montgomery, 2001)

Research Literature Reviews

To use acceptance sampling plans to replace 100% inspection and, at the same time, yield benefits to manufacturer and consumers, it must take consideration with several numbers of OC curves (Dumicic, 2006; Hoying, 2005). They are as follows

1. Increasing of AQL increases the customer's risk, on the other hand an increasing of the producer's risk reduces the consumer's risk.
2. Increasing of LTPD reduces the consumer's risk.
3. When c, AQL and LTPD are fixed; increasing of n can make α higher but β lower.
4. When n, AQL and LTPD are fixed; increasing of c can make α lower but β higher.
5. When n, c and LTPD are fixed; increasing of AQL can make α higher but β stable.
6. When n, c and AQL are fixed; increasing of LTPD can make α stable but β lower.

Figure 1 shows several types of sampling plans. They are attribute sampling plans, variable sampling plans and other sampling plans.

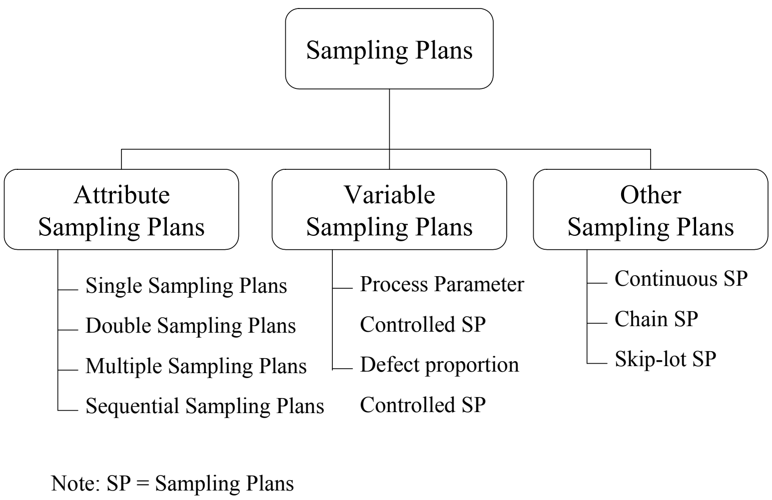

Figure 1 Types of Sampling Plans

Single sampling plan with AQL of 10%, LTPD of 20-29%, α of 5% and β of 10% showed the highest efficiency of 80% (Khan, 2005; Kreetavej, 2005). Several researches showed implementation of single sampling plans to numbers of industrial organizations such as automotive part manufacturing companies and electrical and electronics companies. Development of computer program applications intends to ease repetitive and multi-factors calculations; for example, a sample size (n), an acceptance number (c), a producer's risk (α), a consumer's risk (β), a probability of acceptance (Pa), an average outgoing quality (AOQ) and inspection cost. Moreover, computer program applications were equipped with support functions such as data documentation, high data processing rate at 4.22-14.11 seconds and 100% accuracy. (Kreetavej, 2005; Ngen Rang and Peungsuk, 1996; Hoying, 2005; Labnonkwa, 2007; Wiengharuethai, 2007). This research aims to implement the attribute single sampling plan generated from the computer program application that provides value of n, c, α, β, Pa and AOQ. The program can produce quality record data. The inspection costs are compared among the single sampling plan, 100% inspection and the rectifying single sampling plan which have not been investigated before.

RESEARCH METHODOLOGY

The research methodology consists of a quality inspection data gathering, a suitable sampling plan selection, a quality cost calculation, a computer software generation, a sampling plan implementation and validation. The details of each step are as follows.

Inspection Data Gathering

At a quality inspection data gathering stage, it shows a high inspection cost of approximately 400,000 baht annually ($12,500) as shown in Table 2.

Table 2 Inspection Cost Year 2007

Month	Output (Units)	Lot size (Units)	Numbers of Lot	Inspection Cost/Lot (Baht)	Total Inspection Cost (Baht)
January	19,200	1,920	10.00	3,121.96	31,219.60
February	24,480	1,920	12.75	3,121.96	39,804.99
March	19,200	1,920	10.00	3,121.96	31,219.60
April	19,680	1,920	10.25	3,121.96	32,000.09
May	24,000	1,920	12.50	3,121.96	39,024.50
June	22,080	1,920	11.50	3,121.96	35,902.54
July	22,080	1,920	11.50	3,121.96	35,902.54
August	20,160	1,920	10.50	3,121.96	32,780.58
September	20,080	1,920	10.46	3,121.96	32,655.70
October	24,960	1,920	13.00	3,121.96	40,585.48
November	22,080	1,920	11.50	3,121.96	35,905.54
December	21,600	1,920	11.25	3,121.96	35,122.05
Total	259,600	-	135.21	-	422,120.21

Moreover, the inspection employees have fatigue and boredom from repetitive inspection procedures. Table 3 shows total time for 100% inspection. Every month, the customer reports defect numbers found after receiving the product. Table 4 shows that out of 259,000 units sent out, there were no defects at all (zero defect). A zero defective rate from Table 4 represents a good quality record. Thus, an acceptance sampling plan is considered to replace 100% inspection with the objective to reduce inspection cost and time.

Select an Acceptance Sampling Plan

The next step is to select an appropriate sampling plan. Review of several single sampling plan and inspection cost literatures found that there are three types of sampling plan (Sukchareonpong, 1992)

1. Attributes Sampling Plan which shows a "Pass" or "Fail" outcome. There are a single sampling plan, a double sampling plan, a multiple sampling plan and a sequential sampling plan.
2. Variables Sampling Plan which shows a measurable parameter when inspection.
3. Other Sampling Plan which is used to decide whether to accept or reject lot. There are a continuous sampling plan, a chain sampling plan and a skip-lot sampling plan.

Cost model of sampling plan (Pipatpanyanukul, 1998) are categorized into 6 types. They are costs of a single sampling plan, a 100% inspection, a rectifying sampling plan, a double sampling plan, a rectifying double sampling plan and an accepting without inspection. Literature review proves that an optimal single sampling plan consists of an Acceptance Quality Level (AQL) of 10%, a consumers' risk (β) of 5%, a producers' risk (α) of 10% and Lot Tolerance Percent Defective (LTPD) of 28 as shown in Table 5.

Table 3 Inspection Time of Year 2007

Month	Output (Units)	Lot size (Units)	Numbers of Lot	Inspection Time/Unit (minutes)	Total Inspection Time (hours)
January	19,200	1,920	10.00	2.14	684.80
February	24,480	1,920	12.75	2.14	873.12
March	19,200	1,920	10.00	2.14	684.80
April	19,680	1,920	10.25	2.14	701.92
May	24,000	1,920	12.50	2.14	856.00
June	22,080	1,920	11.50	2.14	787.52
July	22,080	1,920	11.50	2.14	787.52
August	20,160	1,920	10.50	2.14	719.04
September	20,080	1,920	10.46	2.14	716.19
October	24,960	1,920	13.00	2.14	890.24
November	22,080	1,920	11.50	2.14	787.52
December	21,600	1,920	11.25	2.14	770.40
Total	259,600	-	135.21	2.14	92,590.73

Table 4 Defect Parts from the Customer's Inspection Report of Year 2007

Month	Delivered Product (Units)	Lot size (Units)	Numbers of Lot	Numbers of Inspection (Units)	Defective Rate (%)
January	19,200	1,920	10.00	19,200	0
February	24,480	1,920	12.75	24,480	0
March	19,200	1,920	10.00	19,200	0
April	19,680	1,920	10.25	19,680	0
May	24,000	1,920	12.50	24,000	0
June	22,080	1,920	11.50	22,080	0
July	22,080	1,920	11.50	22,080	0
August	20,160	1,920	10.50	20,160	0
September	20,080	1,920	10.46	20,080	0
October	24,960	1,920	13.00	24,960	0
November	22,080	1,920	11.50	22,080	0
December	21,600	1,920	11.25	21,600	0
Total	259,600	-	135.21	259,600	0

Table 5 The most efficient sampling plan parameters

No.	AQL	LTPD	α	β	Efficiency (%)
1	0.01	0.02-0.11	0.05	0.10	54.97
2	0.02	0.04-0.13	0.05	0.10	57.74
3	0.03	0.06-0.15	0.05	0.10	22.33
4	0.04	0.08-0.17	0.05	0.10	51.69
5	0.05	0.10-0.19	0.05	0.10	49.91
6	0.06	0.12-0.21	0.05	0.10	60.47
7	0.07	0.14-0.23	0.05	0.10	41.27
8	0.08	0.16-0.25	0.05	0.10	70.14
9	0.09	0.18-0.27	0.05	0.10	30.31
10	0.10	0.20-0.29	0.05	0.10	80.00

]With inspection cost comparison between the single sampling plan and the rectifying sampling plan with 100% inspection, the most suitable LTPD is 0.28 or 28% (with lowest inspection cost) as shown in Table 6.

Table 6 Inspection Cost Comparison between the Single Sampling Plan and the Rectifying Sampling Plan with 100% inspection

No.	AQL	LTPD	α	β	Single Sampling Plan Inspection Cost (Baht)	Rectify Sampling Plan Inspection Cost (Baht)	Cost Difference
1	0.10	0.20	0.05	0.10	1,621.15	1,582.26	38.89
2	0.10	0.21	0.05	0.10	1,590.19	1,559.02	31.17

3	0.10	0.22	0.05	0.10	1,569.01	1,548.73	20.28
4	0.10	0.23	0.05	0.10	1,547.00	1,535.90	11.10
5	0.10	0.24	0.05	0.10	1,524.03	1,521.95	2.08
6	0.10	0.25	0.05	0.10	1,515.36	1,518.70	-3.34
7	0.10	0.26	0.05	0.10	1,516.01	1,519.51	-3.50
8	0.10	0.27	0.05	0.10	1,500.86	1,499.11	1.75
9	0.10	0.28	0.05	0.10	1,490.88	1,494.40	-3.52
10	0.10	0.29	0.05	0.10	1,497.62	1,511.72	-14.10

Design Computer Program Flowchart and Database Structure

Visual Basic program is used to create a software application. Program flowchart is shown in figure 2. The program allows a user to set a sampling plan, determine a sample size, calculate number of acceptable part, evaluate accepting lot probability and calculate inspection cost. The software evaluation includes sample size and number of defect calculation, program consistency and quality cost calculation. Computer program uses Poisson probability and product details as calculating and output database. A program installation guideline and a user manual are developed for the implementation step. The installation step is designed to compatible with widely use computer as shown in Figure 3 and 4. Security issue is offered by providing a log-in with username and password protection as shown in Figure 5.

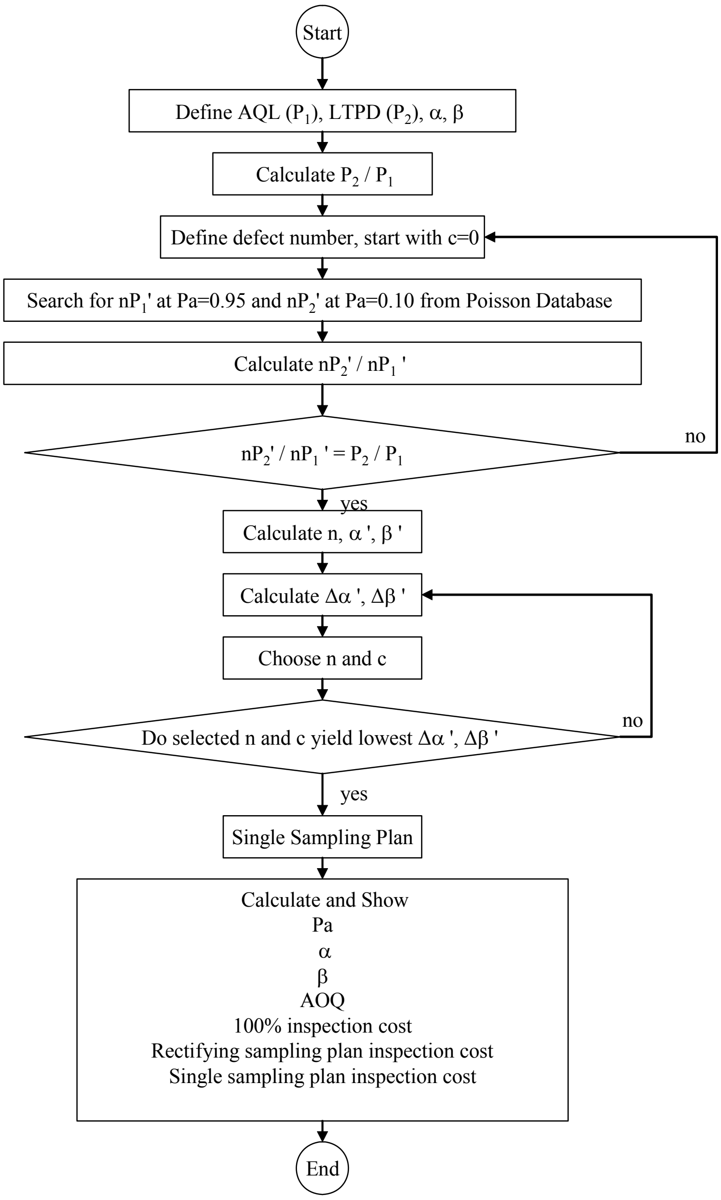

Figure 2 Single Sampling Plan Computer Program Flow Chart

Figure 3 Installation Page

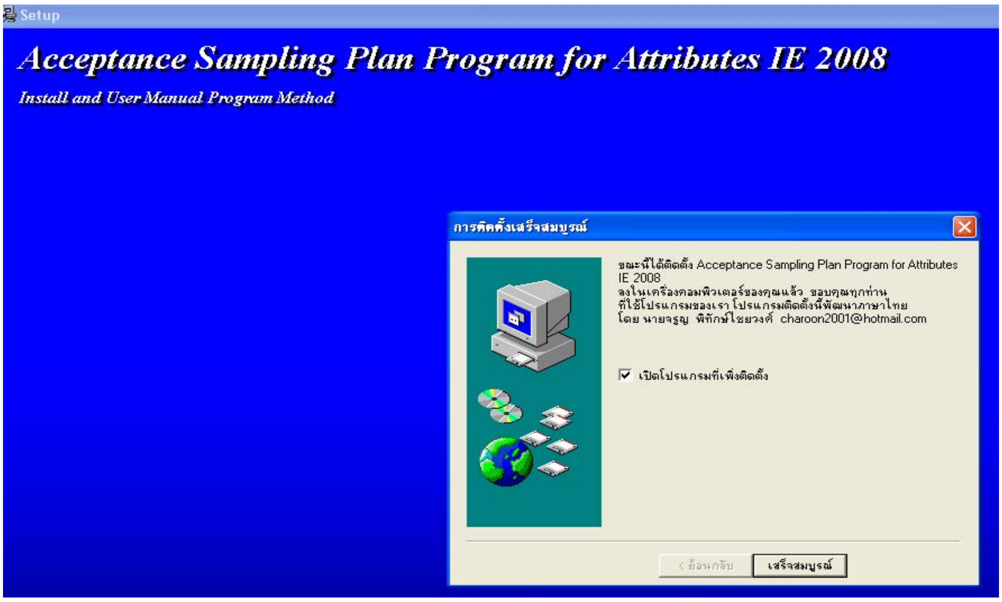

Figure 4 Installation Page

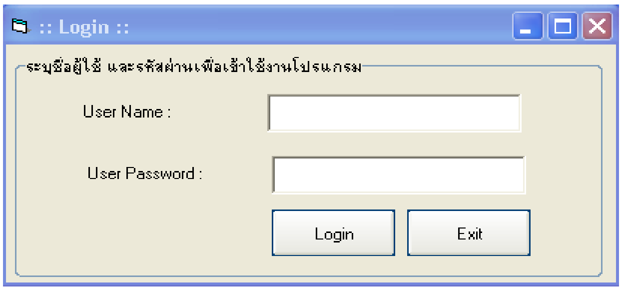

Figure 5 Login with Password Protection

RESULT

The implementation stage lasted 3 months. The factory changed from 100% inspection to the attributed single sampling plans generated from a computer program application as shown in Figure 6. There were 58 lots went through the final inspection with the designed sampling plan as follows.

N (lot size)	=	1,920	units
n (sample size)	=	46	units
c (defective numbers)	=	8	units
AQL	=	10	%
LTPD	=	28	%
Producer's Risk	=	5	%
Customer's Risk	=	10	%
AOQ	=	9.41	%
Pa	=	96.36	% (at 8 defects) and 99.21% (at 0 defect)

Inspection costs are compared among 3 types of inspection plan. Figure 7 shows that the single sampling plan resulted in the lowest inspection cost of 1,490.88 Baht/lot.

After the implementation stage with computer software application, the result shows a 52.25% quality cost reduction per lot and a 97.65% inspection time reduction per lot. Furthermore, the single sampling plan yields minimum producer's risk with $\alpha = 10.54\%$ and minimum consumer's risk with $\beta = 5.41\%$. The computer program application is validated with user's satisfaction survey. The result shows impressive user satisfaction according to shorter calculation time with 100% precision.

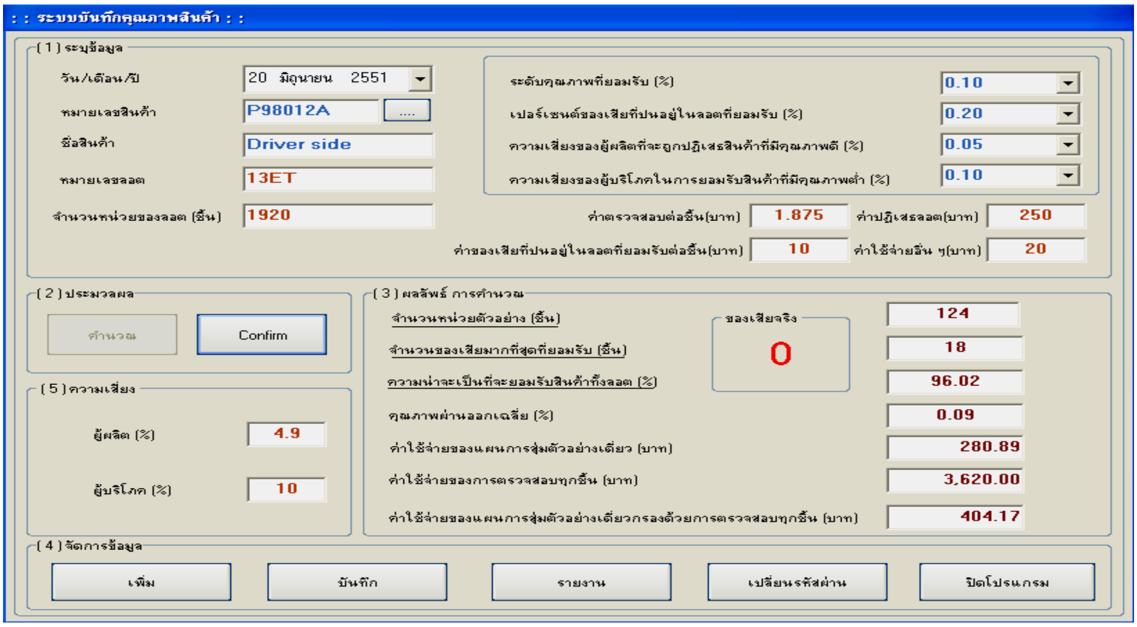

Figure 6 Example of Data Input

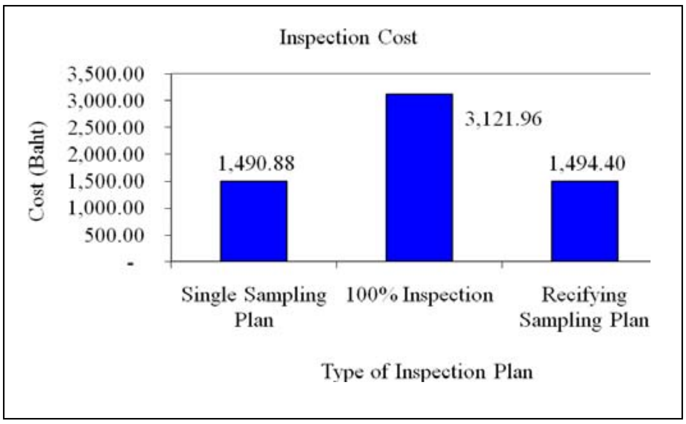

Figure 7 Inspection Costs Comparison

DISCUSSION

Hoying (1999), Kreetavej (2004), Ngen Rang Peungsuk (1996)'s studies are similar in term of a construction of a single sampling plan with n and c calculations. This research enhances from other similar research studies with the considerations of different inspection costs. The selected sampling plan not only minimizes producer's risk and consumer's risk but also minimizes the inspection cost. Visual Basic program has been widely used as a tool for creating a computer application including this research and other studies in this field. The differences are the user interface format and graphic design due to dissimilar research applications. This research studies only the single sampling plan with the producer's risk of 5% and consumer's risk at 10%, AQL 10%, LTPD 28% and lot size of 1,920 units. An investigate of relationships between changing values of producer's risk and consumer's risk and lot size is a possible further study.

CONCLUSION

In conclusion, the attribute single sampling plan and its computer program application can efficiently replace 100% inspection with some advantages. It results in decreasing quality inspection cost 52.25%, reducing inspection time 97.65%, minimizing producer's risk at 4.51% and consumer's risk at 10.54%, less inspection employee and decreasing inspection errors. On the other hand, the disadvantages remain risks of accepting a bad lot and rejecting a good lot, some calculation difficulties. The employee's education is required according to building up knowledge of acceptance sampling plan technique. An enhancement of the computer program application with an automatic command which connects to sensor or inspecting robots can be a future research.

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