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RESEARCH ARTICLE



# Constructing Optimal Quick Switching System with Hurdle Poisson Distribution

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## Abstract

**Objectives:** Optimizing the sum of risks involved in the selection of acceptance sampling plans playing a vital role. This paper uses the Hurdle Poisson distribution to design an optimal quick switching system attribute plan for a given acceptable quality level (AQL) and limiting quality level (LQL) involving a minimum sum of risks. **Methods:** The sum of producer's and consumer's risks has been met for the specified AQL and LQL. The sum of these risks, as well as the acceptance and rejection numbers have been calculated using the Hurdle Poisson distribution. The operating characteristic function for the quick switching system attribute plan has also been derived using the Hurdle Poisson distribution. **Findings:** The producer and the consumer both represent the same party in the final inspection. As a result, the sum of these two risks should be minimized. In this paper, the sum of risks for various operating ratios are tabulated using the Hurdle Poisson distribution. These tabulated values are less than the sum of risks calculated using the Weighted Poisson distribution. **Novelty:** Reducing the sum of risks is the ultimate aim of the work. In this proposed paper, to attain the minimum sum of risks, the authors make an attempt to approach the Quick Switching System Sampling Plan, when the number of defectives in the submitted lots are very less. In other words, the probability of getting defective is very less. This indicates the quality of the lot selected for the inspection to ensure the protection for the consumer. And the plan is also designed in the way that the producer is also not get affected by rejecting a good lot by the consumer. This is the requirement of minimizing the risks.

**Keywords:** Acceptable Quality Level (AQL); Limiting Quality Level (LQL); Minimum Risk Plan; Quick Switching System Sampling Attribute Plan; Operating Characteristic (OC) Function; Hurdle Poisson Distribution

## 1 Introduction

Manufacturing companies strive to provide high quality products, but only some industries have a reputation for product quality. To maintain their reputation, companies must consistently ensure product quality. However, despite consistent production processes, there can be fluctuations in product quality due to identifiable factors. To monitor these variations, a control chart is used in statistical quality control (SQC). The chart visually displays process differences over time and helps to determine whether the process is under control. However, it is no guarantee quality assurance for final products.

To address this problem and minimize the risks for both producers and consumers, acceptance sampling is employed in SQC. Random samples are taken from a lot to determine whether it meets the criteria for acceptance. Acceptance sampling encourages manufacturers to improve product quality and allow consumers to reject defective goods. However, there is a risk that mistakes will be made, for example that good quality lots will be rejected or poor quality lots accepted. These risks are referred to as the producer's risk ($\alpha$) and the consumer's risk ($\beta$). The corresponding quality levels are referred to as the acceptable quality level and the limiting quality level.

Attribute quality characteristics are subjective and cannot be measured quantitatively, whereas variable quality characteristics can be quantified. Acceptance sampling is used to determine the condition of a lot to be inspected based on either attribute or variable quality characteristics. During the inspection, the sample goods are classified as conforming or non-conforming according to the specified quality requirements. Acceptance sampling plans provide standardized criteria for deciding whether to accept or reject a lot, with different plans recommended for different circumstances. The single sampling plan (SSP) is the basic plan with a random sample size (n) and an acceptance value (Ac). If the number of defective units in the sample is less than or equal to Ac, the lot is accepted. However, if the quality improves, the SSP may no longer be efficient. For this reason, a new procedure, the so-called sampling system, has been developed, which contains several sampling plans and rules for switching rules between these plans.

Dodge and Rombaski developed the Quick Switching System (QSS), which includes both normal and tightened inspections, as well as the operating procedure for accepting or rejecting lots in the acceptance sampling plan used by[(1)].

In this paper, the Quick Switching System with the Hurdle-Poisson distribution is used to minimize the risk for producers and consumers in applications such as quality control and acceptance sampling. It models the number of defects or nonconformities and provides a better fit for data with excess zeros. Accurate modeling reduces the producer's risk of falsely rejecting a conforming product and the consumer's risk of accepting a non-compliant product. By capturing the actual distribution of defects, including excess zeros, it enables more accurate decisions and ultimately minimizes risk for both producers and consumers.

The motivation for developing the multidimensional QSS Hurdle-Poisson model is to improve the efficiency of sampling methods in different modes, to enable the creation of customized models for specific scenarios based on a general overarching framework, to broaden the scope of application for such sampling methods, and to provide a solid foundation for future methodological developments and extensions in the field of sampling methods. The authors developed this versatile model as a basic framework for other models such as Repetitive Group Sampling in the Quick Switching Sampling Plan. Its multidimensional nature allows for the derivation of various specialized models suitable for specific cases and scenarios, while maintaining the QSS Hurdle-Poisson model as a general base model.

The weighted Poisson distribution, tables and techniques are provided for determining the QSS m (n; $C_N$, $C_T$) system, which includes the minimized sum of risks for a given AQL and LQL[(2)]. A type-1 Bayesian QSS under the Gamma Zero Inflated Poisson distribution condition was developed by[(3)]. The quick switching sample system for resubmission batches using Gamma Poisson distribution to examine attribute quality parameters of attributes. The efficiency and economic design of the system reduces the overall cost of inspection while meeting the risks for producers and consumers at defined quality standards[(4)]. A variable QSS system that uses a loss-based capability index to minimize the number of samples and meet quality requirements using a nonlinear optimization problem[(5)]. The quick switching sampling system with double inspection ensures high-quality goods by comparing single inspection characteristics with individual quality standards, especially for expensive and high-volume production[(6)]. The Quick Switching System Repetitive Deferred Sampling Plan-2 is designed to reduce the average ASN for both AQL and LQL while ensuring producer and consumer risks are met with a minimal sample size[(7)]. QSS provides quality protection and reduces inspection costs by using fuzzy logic for parameter uncertainties and the neutrosophic Poisson distribution for increased sensitivity and flexibility[(8)].

Compared to existing distributions such as the weighted Poisson distribution, which assumes that the data is a mixture of Poisson distributions, the Hurdle-Poisson distribution takes a fundamentally different approach by explicitly separating zero and non-zero counts and modeling them independently. It models zero counts with a binary component and non-zero counts with a truncated Poisson component. This two-part structure allows the Hurdle-Poisson to capture additional zeros in a more flexible and interpretable way without depending on combinations. In addition, it provides advantages such as the ability to model a wider range of zero-inflated patterns, the separate interpretability of the zero and non-zero processes, and the potential to combine with efficient algorithms such as the quick-switching system for parameter estimation, making it a more natural and flexible approach.

## 2 Methodology

A Hurdle-Poisson model has a mixture of two components with a zero-truncated Poisson distribution (a positive count component) and the probability of zero counts [9]. Unlike the model with zeros, where all zero observations were assumed to have two separate sources, structural and sampling, the Hurdle model assumes that all zero observations have only one origin, "structural".

A generalized fiducial inference method for ZIP and PH distributions is applied to a healthcare dataset, allowing easy calculation and reporting of confidence intervals and mean estimates. It achieves good small sample properties and performs equally well as Bayesian inference [10].

The authors developed a privacy-preserving method (ODAH) for distributed hurdle regression, reducing data exchange and offering better estimation accuracy than meta-analysis in zero-inflated count scenarios [11].

Let the response variables of the d count data be Yi, where d = 1, 2, 3,..., n, where n represents the total quantity of count data. If the count data are Poisson distributed, the Hurdle-Poisson probability distribution is as follows:

$$P(Yi=d)=\begin{cases} \pi & when\ d=0 \\ (1-\pi)\,\dfrac{e^{-\lambda}\lambda^{d}/d!}{1-e^{-\lambda}} & when\ d>0 \end{cases} \tag{1}$$

Where $\lambda > 0$ *and* $0\ < \pi < 1$

The present study proposes a set of tables and processes to determine modified quick switching systems QSS- m(n; $C_N$,$C_T$) in which the sum of risks to producers and consumers risks are reduced for a given acceptable quality level (AQL) and limiting quality level (LQL) using the Hurdle- Poisson distribution.

Table 1 was created using the Hurdle-Poisson model. Although the Hurdle-Poisson model is intended to be accurate in the case of nonconformities, it is more flexible than the zero-inflated model with zeros, as zero results can be both deflated and inflated. The OC function for the QSS m system was developed by Rombaski [1]:

$$P_a=\frac{\dfrac{1}{(1-P_N)}PN+\dfrac{1-P_T^m}{P^m_{T(1-P_T)}}PT}{\dfrac{1}{(1-P_N)}+\dfrac{1-P_T^m}{P^m_{T(1-P_T)}}} \tag{2}$$

Where $P_N$ stands for the probability of acceptance under normal conditions and $P_T$ for the probability of acceptance under tightened conditions.

The formulas for $P_N$ and $P_T$ for the system QSS -m(n; $C_N$,$C_T$) under the assumptions of the Hurdle-Poisson model for d=1 are as follows:

$$P_N=\textstyle\sum_{d=1}^{C_N}(1-\pi)\,\dfrac{e^{-\lambda}\lambda^{d}/d!}{1-e^{-\lambda}} \qquad for\ d=1,2,\ldots.. \tag{3}$$

$$P_T=\textstyle\sum_{d=1}^{C_T}(1-\pi)\,\dfrac{e^{-\lambda}\lambda^{d}/d!}{1-e^{-\lambda}} \qquad for\ d=1,2,\ldots.. \tag{4}$$

The sum of producer and customer risk is expressed as follows:

$$\alpha+\beta=1-P_a(P_1)+P_a(P_2) \tag{5}$$

If the operating ratios $p_2/p_1$ and $np_1$ can be determined, then $np_2$ can be expressed as follows:

$$np_2=\frac{p_2}{p_1}(np_1) \tag{6}$$

If $np_1$ is fixed, the value of $np_2$ is determined from Equation (6) and applied into Equation (5).

A computer programme is used to determine the parameters $C_T$ and $C_N$, which correspond to the minimum of 1-Pa($p_1$)+Pa($p_2$), by searching for $C_T$ = 0(1)30 and $C_N$ =C $_T$ + 1(1)$C_T$ + 15 for given values of $np_1$ and $p_2$/ $p_1$. The risks of the producer and the consumer are then calculated using the $C_N$ and $C_T$ values, for which the sum of the risks is reduced.

## 3 Result and discussion

**Table 1. Parameters of QSS-2 sampling plan for given $p_2/p_1$ and np1 –Hurdle Poisson model for $\pi$ = 0.999**

| | np 1 | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **$p_2/p_1$** | **0.5** | **1** | **1.5** | **2** | **2.5** | **3** | **3.5** | **4** | **4.5** | **5** | **5.5** | **6** | **6.5** |
| 1.5 | 2, 5 20,14 | 1,7 10,22 | 1,9 4,23 | 1,10 11,6 | 1,12 6,4 | 10,35 0,5 | 10,23 0,2 | 10,26 0,1 | 10,28 0,0.6 | 10,29 0,0.4 | 10,30 0,0.2 | 10,32 0,0.2 | 10,33 0,0.1 |
| 2 | | 1,8 1,7 | 1,10 0.6,4 | 1,12 0.3,1 | 1,14 0.1,0.4 | 1,16 0,0.1 | 2,17 0,0.2 | 2,19 0,0.1 | 3,19 0,0 | 3,22 0,0 | 4,22 0,0 | 4,23 0,0 | 5,25 0,0 |
| 2.5 | | 1,9 0.1,1 | 1,11 0,0.6 | 1,13 0,0.1 | 1,15 0,0 | 1,17 0,0 | 2,18 0,0 | 3,20 0,0 | 3,21 0,0 | 4,23 0,0 | 5,24 0,0 | 5,25 0,0 | 6,27 0,0 |
| 3 | | | 1,12 0,0.1 | 1,14 0,0 | 1,17 0,0 | 2,18 0,0 | 2,19 0,0 | 3,21 0,0 | 4,23 0,0 | 5,24 0,0 | 5,25 0,0 | 6,27 0,0 | 7,29 0,0 |
| 3.5 | | | 1,12 0,0 | 1,15 0,0 | 1,17 0,0 | 2,19 0,0 | 3,21 0,0 | 4,22 0,0 | 4,23 0,0 | 5,25 0,0 | 6,27 0,0 | 6,27 0,0 | 7,29 0,0 |
| 4 | | | 1,13 0,0 | 1,17 0,0 | 2,18 0,0 | 2,19 0,0 | 3,21 0,0 | 4,23 0,0 | 5,25 0,0 | 5,25 0,0 | 6,27 0,0 | 7,29 0,0 | 8,31 0,0 |
| 4.5 | | Key | | 1,17 0,0 | 2,19 0,0 | 3,21 0,0 | 3,21 0,0 | 4,23 0,0 | 5,25 0,0 | 6,27 0,0 | 6,27 0,0 | 7,29 0,0 | 8,31 0,0 |
| 5 | | $C_T$,$C_N$ $\alpha$ %, $\beta$ % | | 1,17 0,0 | 2,19 0,0 | 3,21 0,0 | 4,23 0,0 | 4,23 0,0 | 5,25 0,0 | 6,27 0,0 | 7,29 0,0 | 8,31 0,0 | 8,31 0,0 |
| 5.5 | | | | 1,17 0,0 | 2,19 0,0 | 3,21 0,0 | 4,23 0,0 | 5,25 0,0 | 6,27 0,0 | 6,27 0,0 | 7,29 0,0 | 8,31 0,0 | 10,33 0,0 |
| 6 | | | | 1,17 0,0 | 2,19 0,0 | 3,21 0,0 | 4,23 0,0 | 5,25 0,0 | 6,27 0,0 | 7,29 0,0 | 8,33 0,0 | 8,31 0,0 | |
| 6.5 | | | | 2,19 0,0 | 2,19 0,0 | 3,21 0,0 | 4,23 0,0 | 5,25 0,0 | 6,27 0,0 | 7,29 0,0 | | | |
| 7 | | | | 2,19 0,0 | 3,21 0,0 | 4,23 0,0 | 4,23 0,0 | 5,25 0,0 | 6,27 0,0 | 8,29 0,0 | | | |
| 7.5 | | | | | 3,21 0,0 | 4,23 0,0 | 5,25 0,0 | 6,26 0,0 | 7,28 0,0 | 8,30 0,0 | | | |
| 8 | | Key | | | 3,21 0,0 | 4,20 0,0 | 5,25 0,0 | 7,26 0,0 | | | | | |
| 8.5 | | $C_T$,$C_N$ $\alpha$ %, $\beta$ % | | | 3,21 0,0 | 4,23 0,0 | 5,25 0,0 | 7,29 0,0 | | | | | |
| 9 | | | | | 3,21 0,0 | 5,23 0,0 | 5,25 0,0 | 7,29 0,0 | | | | | |
| 9.5 | | | | | 3,21 0,0 | | 5,25 0,0 | 7,29 0,0 | | | | | |
| 10 | | | | | 3,21 0,0 | | | 7,29 0,0 | | | | | |

**Table 2. Parameters of QSS-3 sampling plan for given $p_2/p_1$ and np1 – Hurdle Poisson model for $\pi$ = 0.999**

| | np 1 | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **$p_2/p_1$** | **0.5** | **1** | **1.5** | **2** | **2.5** | **3** | **3.5** | **4** | **4.5** | **5** | **5.5** | **6** | **6.5** |
| 1.5 | 2,8 19,23 | 10,13 0,7 | 10,17 0,0.7 | 10,22 0,0.2 | 10,21 0,0.1 | 10,23 0,0.1 | 10,25 0,0.1 | 10,26 0,0.1 | 10,28 0,0 | 10,29 0,0 | 10,30 0,0 | 10,32 0,0 | 10,33 0,0 |
| 2 | 1,9 4,15 | 10,14 0,1 | 10,17 0,0.2 | 10,20 0,0.1 | 10,21 0,0.1 | 2,19 0,0 | 3,20 0,0 | 4,21 0,0 | 4,23 0,0 | 5,24 0,0 | 5,25 0,0 | 6,27 0,0 | 6,27 0,0 |

*Continued on next page*

*Table 2 continued*

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2.5 | 1,9 | 10,15 | 1,15 | 2,16 | 2,19 | 3,20 | 3,21 | 4,23 | 5,25 | 5,25 | 6,27 | 6,27 0,0 | 7,29 0,0 |
| | 4,3 | 0,0.4 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | | |
| 3 | 2,9 | 1,13 | 1,16 | 2,18 | 2,19 | 3,21 | 4,23 | 4,23 | 5,25 | 5,25 | 6,27 | 7,29 0,0 | 7,29 0,0 |
| | 1,3 | 0,0.1 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | | |
| 3.5 | 1,10 | 1,14 | 1,17 | 2,19 | 2,19 | 3,21 | 4,23 | 4,23 | 5,25 | 6,27 | 6,27 | 7,29 0,0 | 8,31 0,0 |
| | 0.2,0.8 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | | |
| 4 | 1,10 | 1,14 | 1,17 | 2,19 | 3,21 | 3,21 | 4,23 | 5,25 | 5,25 | 6,27 | 7,29 | 7,29 0,0 | 8,31 0,0 |
| | 0.2,0.2 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | | |
| 4.5 | 1,10 | 1,15 | 1,17 | 2,19 | 3,21 | 3,21 | 4,23 | 5,25 | 6,27 | 6,27 | 7,29 | 8,31 0,0 | 8,31 0,0 |
| | 0.2,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | | |
| 5 | 1,11 | 1,15 | 1,17 | 2,19 | 3,21 | 4,23 | 4,23 | 5,25 | 6,27 | 7,29 | 7,29 | 8,31 0,0 | 10,35 0,0 |
| | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | | |
| 5.5 | 1,11 | 1,15 | 1,17 | 2,19 | 3,21 | 4,23 | 4,23 | 5,25 | 6,27 | 7,29 | 8,31 | 8,31 0,0 | 10,35 0,0 |
| | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | | |
| 6 | 1,11 | 1,15 | 1,17 | 2,19 | 3,21 | 4,23 | 5,25 | 6,27 | 6,27 | 8,31 | | | |
| | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | | | |
| 6.5 | 1,12 | 1,15 | 1,17 | 2,19 | 3,21 | 4,23 | 5,25 | 6,27 | 7,29 | | | | |
| | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | | | | |
| 7 | 1,12 | 1,15 | 1,17 | 2,19 | 3,21 | 4,23 | 5,25 | | | | | | |
| | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | | | | | | |
| 7.5 | 1,12 | 1,15 | 1,17 | 2,19 | 3,21 | 4,23 | 6,27 | | | | | | |
| | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | | | | | | |
| 8 | 1,12 | 1,15 | 1,17 | 2,19 | 3,21 | 5,25 | 6,27 | | | | | Key | |
| | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | | | | | | |
| 8.5 | 1,12 | 1,15 | 1,17 | 2,19 | 3,21 | 6,27 | | | | | | $C_T$,$C_N$ | |
| | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | | | | | | $\alpha$ %, $\beta$ % | |
| 9 | 1,12 | 1,15 | 1,17 | | | | | | | | | | |
| | 0,0 | 0,0 | 0,0 | | | | | | | | | | |
| 9.5 | 1,12 | 2,15 | 1,17 | | | | | | | | | | |
| | 0,0 | 0,0 | 0,0 | | | | | | | | | | |
| 10 | 1,12 | 2,15 | 1,17 | | | | | | | | | | |
| | 0,0 | 0,0 | 0,0 | | | | | | | | | | |

**Table 3. Parameters of QSS-4 sampling plan for given $p_2/p_1$ and np1 –Hurdle Poisson model for $\pi$ = 0.999**

| | $np_1$ | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **$p_2/p_1$** | **1** | **1.5** | **2** | **2.5** | **3** | **3.5** | **4** | **4.5** | **5** | **5.5** | **6** | **6.5** |
| 0.4 | 10,15 | 10,17 | 10,20 | 10,21 | 10,23 | 10,25 | 10,27 | 10,28 | 10,29 | 10,30 | 10,32 | 10,33 |
| | 0.2,4 | 0,1 | 0,0.5 | 0,0.3 | 0,0.2 | 0,0.1 | 0,0.2 | 0,0.2 | 0,0.2 | 0,0.2 | 0,0.2 | 0,0.2 |
| 0.5 | 10,15 | 10,17 | 10,20 | 10,21 | 10,23 | 10,25 | 10,26 | 10,28 | 10,29 | 10,30 | 10,32 | 10,33 |
| | 0.2,2 | 0,0.6 | 0,0.3 | 0,0.2 | 0,0.1 | 0,0.2 | 0,0.2 | 0,0.2 | 0,0.2 | 0,0.3 | 0,0.3 | 0,0.3 |
| 1 | 10,15 | 10,18 | 10,20 | 10,21 | 10,23 | 10,25 | 10,26 | 10,28 | 10,30 | 10,31 | 10,32 | 10,34 |
| | 0.2,0.3 | 0,0.1 | 0,0.2 | 0,0.2 | 0,0.3 | 0,0.3 | 0,0.4 | 0,0.4 | 0,0.5 | 0,0.5 | 0,0.5 | 0,0.6 |
| 1.5 | 10,18 | 10,17 | 10,20 | 10,21 | 10,23 | 10,25 | 10,26 | 10,28 | 10,29 | 10,30 | 10,32 | 10,33 |
| | 0.2,0.2 | 0,0.2 | 0,0.2 | 0,0.3 | 0,0.4 | 0,0.5 | 0,0.6 | 0,0.6 | 0,0.6 | 0,0.6 | 0,0.5 | 0,0.5 |
| 2 | | 1,17 0,0 | 2,19 | 3,20 | 10,31 | 4,23 | 5,25 | 6,26 | 6,27 | 7,29 | 8,30 | 8,31 |
| | | | 0,0.2 | 0.2,0.3 | 0,0.5 | 0.3,0 | 0,0.2 | 0.1,0.2 | 0.2,0 | 0,0.1 | 0,0.1 | 0.1,0 |
| 2.5 | | 1,17 | 2,19 | 3,21 | 4,23 | 5,25 | 6,26 0,0 | 6,27 | 7,29 | 8,30 | 8,31 | 10,33 0,0 |
| | | 0.3,0 | 0,0 | 0,0 | 0,0 | 0,0 | | 0,0 | 0,0 | 0,0 | 0,0 | |
| 3 | | 1,17 | 2,19 | 3,21 | 4,23 | 5,25 | 6,26 0,0 | 7,28 | 7,29 | 8,30 | 10,32 | 10,33 0,0 |
| | | 0.3,0 | 0,0 | 0,0 | 0,0 | 0,0 | | 0,0 | 0,0 | 0,0 | 0,0 | |
| 3.5 | | 1,17 | 2,19 | 3,21 | 4,23 | 5,25 | 7,26 0,0 | 7,28 | 7,29 | 8,30 | 10,32 | 10,33 0,0 |
| | | 0.3,0 | 0,0 | 0,0 | 0,0 | 0,0 | | 0,0 | 0,0 | 0,0 | 0,0 | |
| 4 | | | | | | | 7,26 0,0 | 7,29 | 7,29 | 8,30 | 10,32 | 10,33 0,0 |
| | | | | | | | | 0,0 | 0,0 | 0,0 | 0,0 | |

*Continued on next page*

*Table 3 continued*

| | | | |
|---|---|---|---|
| 4.5 | Key | 11,32 0,0 | 10,33 0,0 |
| 5 | $C_T$,$C_N$ $\alpha$ %, $\beta$ % | 11,32 0,0 | 10,33 0,0 |

### 3.1 Selection of a minimum risk $QSS - m(n; C_N, C_T)$ system with minimal risk based on the Hurdle -Poisson distribution

Tables 1, 2 and 3 are used to determine a QSS- m(n; $C_N$,$C_T$) system based on the Hurdle-Poisson distribution for given AQL($p_1$) and LQL($p_2$), which guarantees a minimised sum of risks. For the proposals in Tables 1, 2 and 3 the producer and consumer risk do not exceed 10% each. Tables 3, 4 and 5 report the parameters $C_N$ and $C_T$ of the QSS-m(n; $C_N$,$C_T$) system and the corresponding producer and consumer risk ($\alpha$ and $\beta$, respectively) in the body of the table versus the product of the number of samples n and AQL($p_1$) (i.e., $np_1$). The following approach is used to select the QSS m(n; $C_N$,$C_T$) system for given $p_1$, $p_2$, $\alpha$ and $\beta$.

i. Determine the operating ratio $p_2/p_1$.

ii. Refer to the row of Tables 1, 2 and 3 that is headed with the calculated value of $p_2/p_1$ that is equal to or just below the computed ratio.

iii. To determine the QSS m(n; $C_N$,$C_T$) system parameters $C_N$ and $C_T$, move from left to right in the row defined in step 2 so that the tabulated producer and consumer risks are equal to or slightly lower than the required values.

**Example 1.**

If $p_1$ = 1%, $p_2$ = 2% with $\alpha$= 5% and $\beta$= 5%, then a QSS -2 (Hurdle Poisson Model) is generated as follows:

1. $p_2/p_1$ = 2.0.
2. Calculated $p_2/p_1$ = 2.0.
3. If the value $C_N$ =14 and $C_T$ =1 from the main part of Table 1 are used, one obtains $\alpha$= 0.1% and $\beta$= 4% are obtained instead of the required $\alpha$ = 5% and $\beta$= 5%.
4. $n = np_1/\ p_1$ = 2.5 /0.01 = 250. Similarly, using the above approach can be used to extract the QSS -3 and QSS- 4 systems (Hurdle -Poisson Model) using Tables 2 and 3.

### 3.2 Comparison with the method of Subramani and Haridoss for the selection of QSS-m(n; CN,CT)

To select a modified QSS -m system (m = 2, 3, and 4) for specified $p_1$,$p_2$, and apply the weighted Poisson distribution tables from[2]. The tables offered here are based on the Hurdle- Poisson distribution under the explicit assuming $p_2$/ $p_1$ values and provide the parameters with the associated producer and consumer risks to the extent that their sum is smaller than QSS -m(n; $C_N$,$C_T$) designed by[2].

**Example 2.**

The comparison of QSS-2 is carried out with the aid of Table 3 from[2], which lists the values for different operating ratios:

**Table 4. Comparison of QSS-2 System**

| Given Values | | | | Weighted Poisson Distribution Subramani and Haridoss (2013) | | | | Hurdle Poisson distribution $\pi$ =0.999 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $p_1$ | $p_2$ | $\alpha$ | $\beta$ | $C_T$ | $C_N$ | $\alpha$ | $\beta$ | $C_T$ | $C_N$ | $\alpha$ | $\beta$ |
| 0.01 | 0.05 | 0.01 | 0.01 | 1 | 7 | 0 | 1 | 1 | 17 | 0 | 0 |
| 0.01 | 0.05 | 0.05 | 0.05 | 1 | 6 | 0 | 3 | 1 | 17 | 0 | 0 |
| 0.01 | 0.03 | 0.05 | 0.05 | 1 | 8 | 0.1 | 2 | 1 | 12 | 0 | 0.1 |
| 0.01 | 0.04 | 0.01 | 0.01 | 1 | 10 | 0 | 0.4 | 1 | 13 | 0 | 0 |

In Figure 1, the OC curve of the $QSS-2$ plan (Hurdle Poisson Model) is compared with the corresponding OC curve for the $QSS-2$ plan of (Weighted Poisson Model).

According to the results shown in Table 4, the Hurdle-Poisson distribution reduced the sum of risks compared to the weighted Poisson distribution[2] of the QSS-2 plan.

**Example 3.**

The Comparison of QSS– 3 is carried out with the aid of Table 4 from[2], which lists the values for different operating ratios:

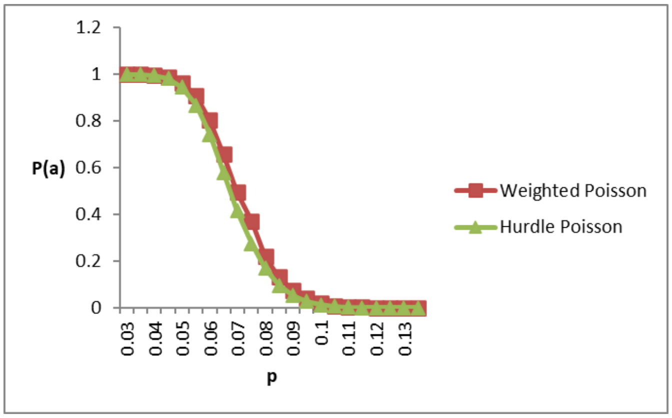


**Fig 1. Operating characteristic curves for $QSS-2$ plans**

**Table 5. Comparison of QSS-3 System**

| **Given Values** | | | | **Weighted Poisson Distribution Subramani and Haridoss(2013)** | | | | **Hurdle Poisson distribution $\pi$ =0.999** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $p_1$ | $p_2$ | $\alpha$ | $\beta$ | $C_T$ | $C_N$ | $\alpha$ | $\beta$ | $C_T$ | $C_N$ | $\alpha$ | $\beta$ |
| 0.01 | 0.02 | 0.01 | 0.01 | 1 | 12 | 0 | 0.1 | 10 | 20 | 0 | 0.1 |
| 0.01 | 0.05 | 0.05 | 0.05 | 1 | 7 | 0 | 2 | 1 | 11 | 0 | 0 |
| 0.01 | 0.03 | 0.05 | 0.05 | 1 | 10 | 0 | 1 | 1 | 13 | 0 | 0.1 |
| 0.01 | 0.04 | 0.01 | 0.01 | 1 | 11 | 0 | 0.4 | 1 | 10 | 0.2 | 0.2 |

In Figure 2, the OC curve of the $QSS-3$ Plan (Hurdle Poisson Model) is compared with the corresponding OC curve for the $QSS-3$ Plan of Weighted Poisson Model.

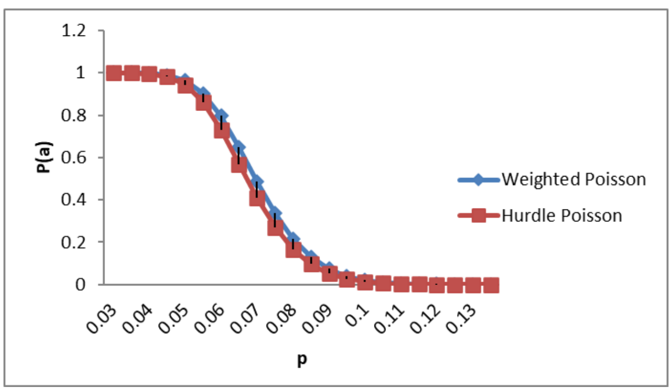


**Fig 2. Operating characteristic curves for $QSS-3$ plans**

According to the results shown in Table 5, the Hurdle-Poisson distribution reduced the sum of risks compared to the weighted Poisson distribution [2] of the QSS-3 plan.

**Example 4.**

The Comparison of QSS– 4 is carried out with the aid of Table 5 from [2], which lists the values for different operating ratios:

In Figure 3, the OC curve of the $QSS-4$ Plan (Hurdle Poisson Model) is compared with the corresponding OC curve for the $QSS-4$ Plan of Weighted Poisson Model.

According to the results shown in Table 6, the Hurdle-Poisson distribution reduced the sum of risks compared to the weighted Poisson distribution [2] of the QSS-4 plan.

**Table 6. Comparison of QSS-4 System**

| Given Values | | | | Weighted Poisson Distribution Subramani and Haridoss(2013) | | | | Hurdle Poisson distribution $\pi$ =0.999 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $p_1$ | $p_2$ | $\alpha$ | $\beta$ | $C_T$ | $C_N$ | $\alpha$ | $\beta$ | $C_T$ | $C_N$ | $\alpha$ | $\beta$ |
| 0.01 | 0.02 | 0.01 | 0.01 | 1 | 14 | 0 | 1 | 1 | 17 | 0 | 0 |
| 0.01 | 0.03 | 0.02 | 0.05 | 1 | 9 | 0 | 3 | 1 | 17 | 0.3 | 0 |
| 0.01 | 0.04 | 0.05 | 0.04 | 1 | 8 | 0 | 3 | 7 | 26 | 0 | 0 |
| 0.01 | 0.05 | 0.01 | 0.05 | 1 | 8 | 0 | 2 | 11 | 32 | 0 | 0 |

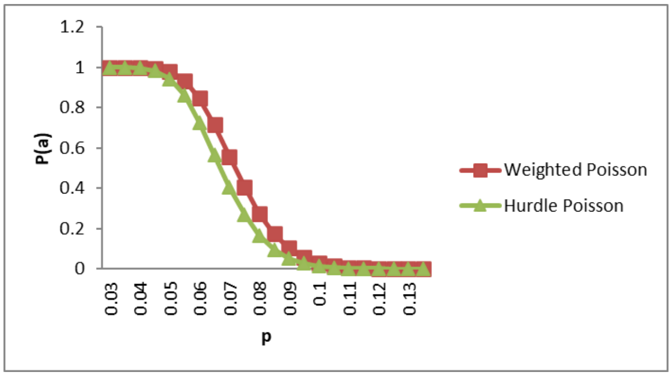


**Fig 3. Operating characteristic curves for $QSS-4$ plans**

## 4 Conclusion

In this article, a quick switching system with Hurdle-Poisson distribution is used to reduce the sum of the risk of a wrong choice. The operating ratios outlined in this plan are frequently used in practice. If the ”producer” and the ”consumer” work in the same company or are impatient, the total number of risks can be reduced instead of fixing them at a given level. It was found that the risk level and sample size are lower for QSS with Hurdle-Poisson distribution than for QSS with weighted poisson distribution. Tables 1, 2 and 3 in this study were created using the Hurdle-Poisson distribution to select the sampling plan for the Quick Switching System.

According to the results of the study, the Hurdle-Poisson distribution reduced the total number of risks compared to the selection of a modified QSS sampling plan using the weighted Poisson distribution. The OC curve of the QSS sampling plan using the Hurdle-Poisson distribution as an optimization criterion shows that the risk of making a wrong decision is minimal (see Figures 1, 2 and 3). Future research will focus on developing robust risk estimation methods for predicting producer and consumer risk through simulations, considering potential deviations or outliers.

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