Determination of non-poison queue system of distribution in the public service sector (case study: Semarang city population and civil registry office)

Sugito¹, A Prahutama¹, D Ispriyanti¹, Mustafid²

¹Statistics Department, Faculty of Science and Mathematics, Diponegoro University, Semarang, Indonesia
²Information System Department, School of Postgraduate, Diponegoro University, Semarang, Indonesia

Corresponding author: sugitostat@gmail.com

Abstract. The public service sector is a sector that is engaged to serve the interests of the community. To get to the public service sector that satisfies the public, there needs to be innovation in system renewal. Many factors need to be analyzed in the public service sector to create a satisfying service. One of the factors determining community satisfaction is the queuing system in the public service area. Queue analysis is an analytical method to measure the performance of a queuing system. The system measured in services includes the number of visitors entering the queue system and the time customers start serving. The queuing system follows the Poisson, Exponential, Normal, or General distribution. For general distribution can be studied into Non-Poisson distribution. In this study, an analysis of the queuing system at the Department of Population and Civil Registration in the city of Semarang included 8 counters. From the analysis results obtained, the general distribution determined is the Dagum and Log Normal distribution. While the size of the performance of the queuing system can be said to be good, because the waiting time for customers in the system is very less.

1. Introduction

In everyday life, queues, queuing, or waiting lines are very often encountered. Queues occur when parties have to wait for service. Queuing process is an occurrence of visitors arriving in a service facility, visitors will queue when the service is full, then will leave the queue system when the visitor has been served [1]. A queue is formed if the number to be served exceeds the available capacity. The waiting situation is also part of the situation that occurs in a series of random operational activities in a service facility.

The Department of Population and Civil Registration ("Dispendukcapil") has the task of assisting in the field of population and civil registration. Civil registration services include services related to births, deaths, marriages, divorces, and other civil registration matters. The number of Indonesian citizens can affect the number of births, deaths, marriages, and divorces. Usually, marriage affects the number of births it can also affect divorce. These things must be reported by the public to the Local Government Office of the Republic of Indonesia in order for the local government to have complete information about the community.

In a service, the best service includes providing fast service so that visitors are not left waiting long. To reduce the waiting time for visitors in queuing, it is necessary to add additional service
facilities to reduce queues or avoid long queues. If long queues often arise, it will result in customer disappointment and the level of trust in these services to decrease. At “Dispendukcapil” there are several counters including moving counters coming / inside, moving coming / outside, legalizing counters, changing data counters, birth counters, death counters, marriage / divorce counters, and deed collection counters [2].

The large number of visitors who come every weekday causes the Semarang City Administration for Civil Service to not be able to serve the community optimally due to the limited service time with visitors who come beyond the service capacity. Visitors come to the service place at random, irregular times, and cannot be served immediately, so they have to wait quite a long time. One of the ways that can be done to reduce the occurrence of queues is to apply queuing analysis to the system [3]. Queue analysis is an analysis used to measure the effectiveness of a service system by looking at the arrival distribution and service distribution. In queue analysis, the most commonly used distributions are Poisson and Exponential distributions. However, there are other distributions used such as the Erlangian distribution. Determination of the queue model based on the arrival distribution and service distribution. If the arrival and service distribution do not have a Poisson or exponential distribution, then the General distribution is used in determining the queuing model [4].

Even though this General distribution can be found a suitable distribution approach. In this paper, an analysis of the counter service system queues in the Department of Population and Civil Registry will be conducted. The approach used is Non-Poisson, which means that if the arrival or service distribution does not have a Poison or exponential distribution, a corresponding distribution will be sought, in this case the distribution being tested is the Dagum distribution and the Log Normal distribution.

2. Literature Review

2.1 Queue Theory

According to [3] a queue is a waiting line for a number of customers who require service from one or more service facilities. A queuing process is a process that deals with the arrival of a number of customers at a service facility, then waiting in a queue if it cannot be served, and finally leaving the service facility after being served. Meanwhile, the queuing system is an association consisting of customers, servants, and a rule that regulates customer service. According to [5], in the queuing process there are six important elements that are closely related to the queuing system, namely: Distribution of Arrivals (Patterns of Arrivals); Distribution of Service Time (Service Pattern); Service Facilities; Discipline of Service; Size In Queue; The Source of the Call

Kendall notation is used to specify the characteristics of a queue. According to [3], the appropriate notation to summarize the main characteristics of parallel queues has been universally standardized in the following format:

\[(a / b / c) : (d / e / f)\]

a : arrival distribution; b : time services distribution; c: the number of server or facility, with c = 1,2,3…); d: service disciplines (FIFO, LIFO, SIRO, and priority service); e : the measurement of systems in the queue. f : the number of customers who want to enter the systems.

2.2 Arrival Distribution and Service Time Distribution

The distribution of arrivals can be calculated by the number of arrivals or the time between consecutive arrivals of two customers. The arrival pattern that occurs may be constant or random. In the queuing system analysis approach, a random arrival pattern is often assumed to follow a Poisson distribution with an average arrival of lambda (λ) [6]. If the number of arrivals follows a Poisson distribution, then the time between arrivals is random and follows the Exponential distribution. The time used to serve a number of customers in a service facility is called service time. Where the service can be done with one or more number of servants with an average service of \(\mu\). If the service
time follows the Exponential distribution, then the service time or $1/\mu$ follows the Poisson
distribution.

2.3 The fit test distribution
The distribution fit test is used to determine the extent to which the observed sample data is in line
with or fits the particular model offered. The most commonly used method of alignment is the
Kolmogorov-Smirnov test. The Kolmogorov-Smirnov test procedure is as follows [7]:
Hypothesis
$H_0$: The sample distribution follows a defined distribution
$H_1$: The sample distribution does not follow a defined distribution
The statistics of testing $D = \max_{1 \leq i \leq r} \{|S(x_i) - F_o(x_i)|\}$
With $S(x_i)$ is the cumulative distribution of the sample from the population; $F_o(x_i)$: the cumulative
distribution of the theoretical data from the hypothesized distribution. The criteria of testing, reject $H_0$
for $D > D^*(\alpha)$. Table $D^*(\alpha)$ is Kolmogorov Smirnov table.

2.4 The queue model of $(G/G/c) : (GD/\infty/\infty)$
According to [2] the queue model $(G/G/c) : (GD/\infty/\infty)$ is a queuing model with a general distribution
pattern of arrivals ($\lambda$) and a general distribution service pattern with the number of service facilities as
much as $c$. The queuing discipline used in this model is FIFO (First In First Out), the maximum
capacity allowed in the system and infinite call sources.

For $r = \lambda/\mu$ and $\rho = \lambda/c\mu$, we get the probability for 0 customer can be written as:

$$P_0 = \left\{ \begin{array}{ll}
\sum_{n=0}^{c-1} \frac{r^n}{n!} + \frac{r^c}{c!(1-\rho)} \\
\end{array} \right\}^{-1}$$

While the probability for $n$ customers can be written as:

$$P_n = \left\{ \begin{array}{ll}
\frac{r^n}{n!} P_0, for n < c \\
\frac{r^n}{c! c^{n-c}} P_0, for n \geq c
\end{array} \right\}$$

So the measurement of systems performance in $(G/G/c) : (GD/\infty/\infty)$ as follows:

1. The number of customers expected in the queue
$$L_q = \left( \frac{r^c}{c!(1-\rho)} \right) P_0 \frac{\mu^2 v(t) + v(t')^2}{2};$$
   with $v(t) = \left( \frac{1}{\mu^2} \right)^2$ and $v'(t') = \left( \frac{1}{\mu^2} \right)^2$

2. The estimated number of customers in the system
$$L_s = L_q + r$$

3. The estimated waiting time in queue is $W_q = \frac{L_q}{\lambda}$

4. The estimated waiting time in the system is $W_s = \frac{L_s}{\lambda} = W_q + \frac{1}{\mu}$

2.5 Normal Distribution
According to [8], Normal distribution is a continuous distribution of odds, the graph is called a normal
curve which is bell-shaped and describes various data sets. The probability distribution of the
continuous normal variable depends on two parameters, namely $\mu$ and $\sigma$ with the density function of
the normal random variable $X$, with mean $\mu$ and variance $\sigma^2$.

$$f(x; \mu, \sigma) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2}$$
2.6 Triangular Distribution
According to [8] the triangular distribution is a continuous distribution with three parameters, namely the minimum value a, the maximum value b and the most likely value m with a≤m≤b. The Triangular distribution is denoted by Triangular (a, m, b). The probability of the Triangular distribution density function is
\[
f(x) = \begin{cases} 
\frac{2(x - a)}{(m - a)(b - a)}, & \text{for } a \leq x \leq m \\
\frac{2(b - x)}{(b - m)(b - a)}, & \text{for } m \leq x \leq b \\
0, & \text{otherwise}
\end{cases}
\]

2.7 Logistic Distribution
According to Kus and Kaya (2006), if X has a logistical distribution with the location parameter μ and the scale parameter σ, then the probability density function and the distribution function of X are given respectively:
\[
f(x; \theta) = \frac{\exp \left( \frac{x - \mu}{\sigma} \right)}{\sigma \left(1 + \exp \left( \frac{x - \mu}{\sigma} \right) \right)}; x \in \mathbb{R}, \mu \in \mathbb{R}, \sigma \in \mathbb{R}
\]

2.8 Dagum Distribution
According to [9] the Dagum distribution is a special case of the Generalized Beta II distribution with the Generalized Beta II distribution parameter, namely q = 1. The probability density function of the Generalized Beta II distribution is:
\[
f(x; a, b, p, q) = \frac{apx^{ap-1}}{b^p \left[1 + \left(\frac{x}{a}\right)^p\right]^{p+q} B(p, q)}; x > 0, a, b, p, q > 0
\]
For B(p, q) is function of Beta as follows:
\[
B(p, q) = \int_0^1 x^{p-1}(1 - x)^{q-1} dx
\]
A random variable X is said to have a Dagum distribution with parameters (a, b, p) if and only if the probability density function of X is:
\[
f(x; a, b, p) = \frac{apx^{ap-1}}{b^p \left[1 + \left(\frac{x}{a}\right)^p\right]^{p+1} B(p, q)}; x > 0, a, b, p > 0
\]

2.9 Lognormal Distribution
According to [10], if X is a random variable with a normal distribution, then Y = ln(X) has a log normal distribution (X~LN(μ, σ²)) with parameters μ and σ², if and only if it has the density function of X defined as follows:
\[
f(x|\mu, \sigma^2) = \frac{1}{x\sigma\sqrt{2\pi}} e^{-\frac{1}{2\sigma^2}(\ln x - \mu)^2}; \quad x > 0, \mu \in (-\infty, +\infty), \sigma^2 > 0
\]
3. Methodology of Research

The data used in this study are primary data, namely data obtained from direct observations and records of visitors to the Semarang City Administration Office. The research was conducted for 5 days starting at 07.00-15.00 for Monday - Thursday and 07.00-12.00 for Friday. The variables used in this study were data on the number of arrivals and service times of visitors at each Semarang City “Dispendukcapil” counter. The steps taken in implementing the research are as follows:

1. Conducting research directly at the Semarang City Civil Service Office, by observing and recording directly to obtain data on the number of arrivals and time of service data in the time unit set by the researcher.
2. Perform a steady state check, that is, the average number of visitors who come does not exceed the average number of visitors served. If the data does not meet steady state conditions, it will be followed up by increasing the number of services or speeding up the service time according to existing conditions.
3. Conduct a distribution fit test for data on the number of arrivals and time of service using the Kolmogorov Smirnov test.
4. Determine the appropriate queuing model. In determining the queue model using Kendal Lee's notation with the format (a / b / c) : (d / e / f).
5. Determine the performance measure of the queuing system that occurs at each Semarang City “Dispendukcapil” Office counter, including the estimated number of visitors in the system (L_s), the estimated number of visitors in the queue (L_q), the estimated total time in the system (W_s), and time waiting for the estimated queue (W_q).
6. Perform analysis based on the results of the calculation of system performance measures.

4. Results and Discussions

4.1 Steady State testing

The first step in queuing analysis is steady state testing. The steady state test in this study was carried out on the data on the number of arrivals and service times at each counter. Steady state conditions are met if the value of \( \rho < 1 \). If the steady state conditions are not met, what must be done is to change the observation time interval or change the data. Steady state testing as follows:

**Table 1. Service Facility Usability Level**

| Counter                  | c | \( \lambda \) | \( \mu \) | \( \rho = \frac{\lambda}{c \cdot \mu} \) |
|--------------------------|---|--------------|------|---------------------------------|
| Legalized counter        | 2 | 12.2973      | 20.3848 | 0.301629                        |
| The Change of Data counter | 1 | 10.75676     | 17.96534 | 0.59875                          |
| Birth counter            | 2 | 12.37838     | 14.71148 | 0.840705                         |
| Mortality counter        | 2 | 10.86486     | 14.92066 | 0.364088                         |
| “KutipanKedua” counter   | 1 | 5.918919     | 11.69692 | 0.506024                         |
| Biometric counter        | 2 | 6.972973     | 12.53028 | 0.278245                         |
| Registration citizen     | 2 | 6.918919     | 21.30741 | 0.162359                         |
| Electronic ID card       | 1 | 8.162162     | 19.30901 | 0.420927                         |

Based on the results from Table 1, it is obtained that the service facility usability level (\( \rho \)) value at each counter in the Semarang City “Dispendukcapil” is less than 1, so it can be concluded that of the nine counters have met steady state conditions.

4.2 The fit test distribution the number arrival of visitors

H0: Data on the number of visitors in counter is Poisson distributed.

H1: Data on the number of visitors in counter is Non Poisson distributed.
Based on Table 2, the value of $D > D_{\text{table}}$ or the p-value < value $\alpha = 5\%$ for all counters, then $H_0$ is rejected. This means that the data on the number of visitors at each “Dispendukcapil” counter in Semarang City does not Poisson distribution.

### Table 2. The Kolmogorov Smirnov’s test for the number of arrival visitors

| Counter               | P-Value     | $D$     | $D_{\text{table}}$ | Decision   |
|-----------------------|-------------|---------|---------------------|------------|
| Legalized counter     | 0.03643     | 0.23265 | 0.218               | $H_0$ Rejected |
| The Change of Data counter | 0.000155  | 0.35763 | 0.218               | $H_0$ Rejected |
| Birth counter         | 0.01331     | 0.26025 | 0.218               | $H_0$ Rejected |
| Mortality counter     | 0.000881    | 0.32315 | 0.218               | $H_0$ Rejected |
| “KutipanKedua” counter | 0.01298   | 0.2609  | 0.218               | $H_0$ Rejected |
| Biometric counter     | 0.01079     | 0.26566 | 0.218               | $H_0$ Rejected |
| Registration citizen  | 0.0048      | 0.28551 | 0.218               | $H_0$ Rejected |
| Electronic ID card    | 0.00489     | 0.28509 | 0.218               | $H_0$ Rejected |

4.3 The fit test distribution of time served

Hypothesis

$H_0$: Service time data at the counter has an exponential distribution

$H_1$: Service time data at the counter has an Non-exponential distribution

### Table 3. The Kolmogorov Smirnov’s test of time served

| Counter               | P-Value     | $D$     | $D_{\text{table}}$ | Decision   |
|-----------------------|-------------|---------|---------------------|------------|
| Legalized counter     | 6.77x10^{-12} | 0.19135 | 0.0637              | $H_0$ Rejected |
| The Change of Data counter | 2.60x10^{-07} | 0.1691  | 0.0682              | $H_0$ Rejected |
| Birth counter         | < 2.2x10^{-15} | 0.20212 | 0.0635              | $H_0$ Rejected |
| Mortality counter     | 1.05x10^{-06} | 0.16302 | 0.0678              | $H_0$ Rejected |
| “KutipanKedua” counter | 0.00322   | 0.12118 | 0.0919              | $H_0$ Rejected |
| Biometric counter     | 0.000387    | 0.12872 | 0.0847              | $H_0$ Rejected |
| Registration citizen  | 6.31x10^{-01} | 0.14227 | 0.085               | $H_0$ Rejected |
| Electronic ID card    | 2.63x10^{-06} | 0.14973 | 0.0783              | $H_0$ Rejected |

Based on Table 3, the value of $D > D_{\text{table}}$ or p-value < value $\alpha = 5\%$ for all counters, then $H_0$ is rejected. This means that the service time data at each “Dispendukcapil” counter in Semarang City does not an exponential distribution. Based on testing the fit of the distribution for the number of arrivals and service times, it shows that both have a General distribution. Therefore, an estimation of the distribution approach is carried out to determine the approximate distribution of the number of arrivals and service times. The distributions used for the approach include the Logistic distribution, Normal distribution, Triangular distribution, Meat distribution, and Lognormal distribution.

4.4 The queue model for each counter

In Addition, we have to find the specific distribution of General distribution. In this research, we have been testing some of distribution such as Logistic distribution, Dagum distribution, Normal distribution, Triangular distribution and Log Normal distribution. We used Kolmogorov-smirnov’s test to test the fit distribution for number of arrival and the time of served. Based on distribution suitability testing using the Kolmogorov Smirnov test, a queuing model is obtained with the following distribution in table 4.

Based on Table 4, for the model (Normal / Dagum / 1):( GD / $\infty$ / $\infty$) shows that the queuing system model with the number of arrivals follows the Normal distribution, service time follows the Dagum distribution, with service facilities 1, queuing discipline is the first to come first served (FIFO), and the capacity of visitors who come and the source of the calls is unlimited. Model (Logistic /
Dagum / 2) (GD / ∞ / ∞) is a queuing system model with the number of arrivals following the Logistic distribution, service time following the Dagum distribution, with 2 service facilities, queuing discipline is first come first served (FIFO) as well as the number of visitor capacity and unlimited calling resources. Model (Triangular / Dagum / 2) (GD / ∞ / ∞) is a queuing system model with the number of arrivals following the Triangular distribution, service time following the Dagum distribution, with service facilities 1, queuing discipline is first come first served (FIFO) as well as the capacity of visitors who come and call resources are not limited.

Table 4. Queue model for each counter at the Semarang City “Dispendukcapil”

| Counter                     | Model of queue                        |
|-----------------------------|---------------------------------------|
| Legalized counter           | (Logistic / Dagum / 2):(FIFO / ∞ / ∞) |
| The Change of Data counter  | (Normal / Dagum / 1):(FIFO / ∞ / ∞)   |
| Birth counter               | (Triangular / Dagum / 2):(FIFO / ∞ / ∞) |
| Mortality counter           | (Logistic / Dagum / 2):(FIFO / ∞ / ∞) |
| “Kutipan Kedua” counter     | (Normal / Dagum / 1):(FIFO / ∞ / ∞)   |
| Biometric counter           | (Normal / Dagum / 2):(FIFO / ∞ / ∞)   |
| Registration citizen        | (Normal / Dagum / 2):(FIFO / ∞ / ∞)   |
| Electronic ID card          | (Normal / Lognormal / 1):(FIFO / ∞ / ∞) |

4.5 System performance system for each counter

After the queuing model is known for each counter, the next step is to determine the system performance measurement. In determining system performance measures for the number of arrivals and service times, use the General distribution. The results obtained are as follows:

Table 5. Performance Measures of Semarang City “Dispendukcapil” Visitor Service System

| Counter                        | L_q | L_s  | W_q | W_s  | P_o  |
|--------------------------------|-----|------|-----|------|------|
| Legalized counter              | 0.00027 | 0.60618 | 0.00002 | 0.04908 | 0.53497 |
| The Change of Data counter     | 0.00352 | 0.54281 | 0.00033 | 0.05046 | 0.46071 |
| Birth counter                  | 0.00101 | 0.84242 | 0.00008 | 0.06806 | 0.40775 |
| Mortality counter              | 0.00072 | 0.72890 | 0.00007 | 0.06709 | 0.46618 |
| “Kutipan Kedua” counter        | 0.00929 | 0.51532 | 0.00157 | 0.08706 | 0.49398 |
| Biometric counter              | 0.00063 | 0.55712 | 0.00009 | 0.07990 | 0.56465 |
| Registration citizen           | 0.00010 | 0.32482 | 0.00015 | 0.04695 | 0.72064 |
| Electronic ID card             | 0.00270 | 0.42363 | 0.00033 | 0.05190 | 0.57907 |

Based on Table 5, it can be explained that for legalized counters, the value of the performance measures of this counter queuing system is the average number of visitors estimated in the system (L_s) is 0.60618 every 60 minutes. The average estimated number of visitors in line (L_q) is 0.00027 every 60 minutes. The estimated waiting time in the system (W_s) is 2.94470 minutes, while the estimated waiting time in queue (W_q) is 0.00133 minutes. The queuing system has the opportunity for unemployed service officers (P_o) is 53.497%. Based on Table 7, the most queues are at the Birth counter. Meanwhile, the most waiting time was at the “kutipan kedua” counter for 5.2236 minutes.

5. Conclusion

Non-Poisson queue modeling has been carried out for services at the Semarang municipal “Dispendukcapil”. The variables used are the number of arrivals and time of service. This model can be developed for the number of arrivals and the number of services. The system performance measurement in each counter is almost the same, except for registration citizen counters. The queuing system has the opportunity for unemployed service officers (P_o), which average 40% until 50%, but
for registration citizen counters, the opportunity to be unemployed is 72%. It shows that registration counters is ineffective, so that the system needs to be repaired. But overall, all counters in “Dispendukcapil” have been serving customers very well.

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