Queue Simulation for Flood Relief Distribution Following Disasters Using Parametric Regression Technique

Sugeng Prayitno, Rian Farta Wijaya

Abstract

The distribution of post-flood disaster aid often faces obstacles such as long queues, extended waiting times, and inefficient aid distribution. This condition can hinder the fulfilment of the basic needs of the affected community, especially during the emergency response phase. This research aims to analyse the queuing system in the process of distributing aid after a flood disaster and to simulate a more effective service pattern using the parametric regression method. This method is used to identify the influence of certain variables, such as the number of refugees, the capacity of officers, and service time, on queue length and waiting time. Research data were obtained from field observations, documentation, and interviews at the aid distribution locations. The analysis results show that the increase in the number of aid recipients, not matched by service capacity, has caused a significant increase in queues. The simulation conducted shows that adjusting the number of officers and accelerating service time can reduce queue length and improve the efficiency of aid distribution. Thus, the application of queue simulation based on parametric regression can serve as an aid in planning a faster, more accurate, and organised aid distribution system in post-flood disaster conditions.

***Keywords**: Queue Simulation, Aid Distribution, Post-flood Disaster, Parametric Regression, Service Efficiency*

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Introduction

Indonesia is a country with a high level of vulnerability to hydrometeorological disasters, and floods are among the most frequent disasters. The Indonesian Disaster Data Portal owned by BNPB, updated on April 12, 2026, recorded 370 flood incidents in just the early months of 2026. The BNPB bulletin for December 2025 also mentioned that floods accounted for 154 incidents or 62.86% of the total disasters that month, thus confirming that floods remain a dominant threat in the national disaster management system. This fact shows that flood management cannot be understood as an incidental event, but as a recurring public issue that requires quick, measured, and efficient response governance. Floods are overflowed water that cannot be contained by rivers; floods are also a disaster because they disrupt community activities. There is a strong suspicion that extensive deforestation is what caused the flood tragedy in the Sumatra region. [1], [2].

In the context of disaster management, response speed becomes a crucial factor because the emergency response phase focuses on meeting the urgent needs of the affected community. UNDRR defines disaster response as efforts focused on immediate and short-term needs, requiring effective, efficient, and timely actions. In Indonesia, this is also in line with Law Number 24 of 2007, which emphasises that disaster management is the responsibility of the government and local governments, and must be carried out in a planned, integrated, coordinated, and comprehensive manner. High and sustained rainfall is one of the natural processes that cause floods [3]. Thus, the distribution of post-flood aid is not merely an administrative technicality, but rather a part of the state's obligation to ensure the protection of the community during emergencies. There are 5 factors causing flooding in the downstream area of the Sekadau watershed, namely: 1) high rainfall, 2) topographic conditions, 3) land use changes, 4) residential areas along the riverbanks, 5) waste issues [4].

The urgency is even stronger because post-flood emergency assistance involves the basic needs of the community, such as food, clean water, medicine, clothing, and other emergency supplies. BNPB regulations regarding logistics management and aid distribution emphasise that disaster logistics management includes planning, procurement, warehousing, and distribution so that handling objectives can be achieved effectively and efficiently. How well the Cash Social Assistance program was implemented during the epidemic [5]. The principles of disaster management within the framework of Indonesian law also emphasise aspects of speed and accuracy, prioritisation, coordination, and integration. This means that the success of aid distribution is not only measured by the amount of aid available but also by the system's ability to deliver aid to recipients quickly, orderly, and equitably. Village officials' dedication, community involvement, and well-defined rules are all aspects that support the distribution of social aid [6].

However, in field practice, post-flood aid distribution often faces serious operational problems. When the number of aid recipients increases rapidly, while the number of staff, service counters, recording capacity, and verification mechanisms are limited, queues can easily form. Long queues have the potential to cause distribution delays, crowd accumulation, uncertainty in waiting times, and even social tensions at service locations. Research on disaster relief centers shows that relief facilities can be represented as a queueing system with uncertainty in recipient arrivals, service times, and staff availability. These findings emphasise that the issue of aid distribution is not only related to the availability of logistics but also to the design of the service system at the distribution points. Inaccurate statistics, a lack of community understanding and socialisation, and unclear inspection procedures are the primary causes of the unequal distribution of social assistance [7].

From the perspective of operations management, queue theory becomes a relevant approach to analyse the situation. Queue systems help researchers understand the relationship between the arrival rate of aid recipients, the service rate of officers, the number of service facilities, the length of the queue, and the waiting time. Through this approach, researchers can identify whether the service capacity is still able to meet the demand or if it is already in an overload condition. Queue system simulation studies across various services show that simulations can be used to evaluate service configurations and optimise the number of counters or staff without having

to directly change the real system. Therefore, queue simulation is very important in the post-disaster context, when decisions must be made quickly, but still require a strong analytical foundation.

However, classical queue analysis often uses overly simplistic assumptions, such as constant arrival patterns or homogeneous service times. In post-flood situations, such assumptions often do not align with field conditions. Service time can vary depending on the number of recipients, the type of assistance provided, the identity verification process, the capacity of the personnel, and the condition of the distribution facilities. Therefore, this research requires an approach that can capture the relationships between these variables more realistically. Parametric regression becomes relevant because it allows researchers to model the influence of independent variables on service duration or waiting time with a specific distribution form that can be estimated from empirical data. Duration model-based studies show that parametric models can be used to simulate the probabilistic relationship between disaster victim factors.

Literature Review

2.1 Definition of Social Assistance

The definition of social assistance according to the Minister of Home Affairs Regulation Number 32 of 2011 [8] is the provision of assistance in the form of money or basic necessities from the local government to individuals, families, and/or communities in a selective manner. The definition of social assistance according to the Social Counselling Center [9] is a program of fund or goods transfer aimed at reducing poverty by distributing prosperity and protecting households from changes in income conditions, where the assistance is intended to meet the minimum standard of living and minimum nutritional standards, as well as helping households to anticipate existing risks.

Meanwhile, the definition of social assistance according to the Minister of Finance Regulation Number 254/PMK.05/2015 (Kemenkeu_RI, 2020) on Social Assistance Expenditure at State Ministries/Institutions is an expenditure in the form of money, basic necessities, or services provided by the Government to the poor or underprivileged to protect the community from the possibility of social risks and to improve economic capacity.

2.2 Flood

Flooding is a disaster caused by high rainfall and insufficient drainage systems, resulting in water accumulation in areas that are undesirable for the local community. Floods can also occur due to the damage to the available water drainage system, causing low-lying areas to be affected by floodwaters. [10]. Flooding is an event where water inundates land (non-swamp areas) caused by high rainfall and the topography of the region, which consists of low-lying and concave areas. In addition, floods can also be caused by the low infiltration capacity of the soil to absorb water. According to [11], the causes of flooding are the rise in water levels due to heavy rainfall, temperature changes, dam or levee breaches, and the blockage of water flow at several points elsewhere.

2.3 Simulation

Simulation can be conducted to solve vehicle queueing problems. Simulation is an artificial experiment simplified into an operating system process that accounts for time with the aim of understanding and/or improving the system [12].

According to [13], the sequence of processes that must be followed in creating a simulation model is as follows:

1. Analyse the problem and gather information
2. Collect data
3. Build the model
4. Verify the model

5. Validate the model
6. Design and create simulation scenarios
7. Analyse the output 8. Make final recommendations

According to Kakiay (2004), who states that simulation is a system used to solve real-life problems full of uncertainty by using certain methods or models that utilise computers to obtain solutions. By conducting simulations, it can provide alternatives and also solutions to solve the problems being researched. The simulation model describes the relationship between the input and output of a complex system. The main advantages of the simulation method are as follows (Hukum & Kelton, 2000):

1. A developed model can be reused repeatedly to analyse new models.
2. Simulation estimates the performance of the system under review in desired conditions.
3. Alternatives of the design system can be compared through simulation to see which one best meets the desired needs.
4. In simulation, we can maintain better research conditions than when conducted on the actual system.
5. Simulation allows us to conduct long-term system studies in a short period.

According to Suryani (2006), in conducting a simulation, there are several steps that need to be taken, including:

1. System definition. This step includes: determining system boundaries and identifying significant variables.
2. Model formulation: formulating the relationships between the components of the model.
3. Data collection: identifying the data required by the model according to the purpose of model creation.
4. Model construction. In model preparation, it needs to be adjusted to the type of simulation language that will be used.
5. Model verification: the process of checking whether the model is free from errors. 6. Model validation is the process of testing whether the created model corresponds to the actual system. Yaman Barlas in his journal titled "Multiple Test for Validation of Systems" Dynamics Type of Simulation Model", explains two testing methods:

   a. Mean Comparison

$$E1 = \frac{(\bar{S} - \overline{A})}{\bar{A}}$$

   Dimana: S = Nilai rata-rata hasil simulasi
   A = Nilai rata-rata data actual
   Model dikatakan valid bila E1 ≤ 5%

   b. Amplitude Variation Comparison

   To compare the variation between the simulation output and the available historical data, we can calculate the model standard deviation (Ss) and the historical standard deviation (SA). These two standard deviations are then compared using the "Percent Error in The Variations" or $E2$, with the following formula:

$$E_2 = \frac{|S_S - S_A|}{|S_A|}$$

   A model is considered valid if $E2 \leq 30\%$
6. To determine the required number of replications, a calculation of the number of replications is performed. In this case, the method used to calculate the number of replications is the absolute error method. The confidence interval used is 95%. Here are the calculations:
   n = 30
   n – 1 = 29
   α = 0.05
   hw = (n−1, ∝/2) x S √n

= (2.04523) x S √30

7. The value of hw or Absolute Error (β) is the amount of error that is tolerated within the system and is expressed in terms of the number of errors. Next, calculate the value of n', which is the new replication value needed, using the half width value obtained from the previous calculation with the following formula:
   n' = ((Z0,05/2) x S hw)2
   = (1,96 x S hw)2

2.4 Queueing Theory

Queueing theory is a theory related to the mathematical study of queues or lines. Queueing theory always pertains to all aspects of the customer situation in obtaining services (both service and goods). A queue is a line of people or goods waiting to be served or includes a company's lineup that can determine the most convenient time and facilities to serve customers effectively and efficiently. Erlang revealed that queue theory can be seen in customers who receive service first based on who arrives earlier. In this case, someone in line may arrive at the same time or at different times.

A queue is a condition where there is a delay in serving an object due to a queue because the service is busy. Queues occur due to an imbalance between availability and the balanced need to serve. Queues also often occur due to differences in arrival times and varying service times (Yamit, 2004). During busy times, operators are overwhelmed in serving callers quickly, causing callers to queue and wait for their turn. The original problem of A.K. Erlang only addressed the calculation of delay from an operator (Joni, et al., 2011). Queueing Theory is an analytical tool used to solve queue problems; this theory provides information for decision-making by predicting various characteristics of the queue. (Aji, et al., 2012).

2.5 Parametric Regression

Parametric regression is one of the regression models used to analyse the relationship between the response variable (Y) and the predictor variable (X). In regression, a curve is formed based on the data used. Parametric regression has a patterned curve shape, such as linear, quadratic, or exponential patterns, and so on. In parametric regression, it can be used to determine the linear relationship with the formed model. The following is a multiple regression model given n observations with p predictor variables (Hardle, 1994):

$$y_i = \beta_0 + \sum_{k=1}^{p} \beta_k x_{ik} + \varepsilon_i \; ; \; i = 1,2,\dots,n \; ; \; k = 1,2,\dots,p$$

Explanation:
yi = Response variable of observation i
xik = Predictor variable k of observation i
βk = Regression coefficient on xk
$\beta 0$ = Intercept
εi = Residual of observation i

If written in matrix form, it is as follows:

$$Y = \mathrm{X}\mathbf{Q} + \boldsymbol{\varepsilon}$$

2.6 Queueing Theory

Nonparametric regression is one type of regression model besides parametric regression. Nonparametric regression is very suitable for detecting the presence of nonlinearity and nonlinear relationships in the model (Eubank, 1999). The nonlinearity can be observed in the curve that is formed. The formed nonparametric regression curve does not contain a specific pattern or can be said that the shape of the curve is unknown. The following is a general model of nonparametric regression:

$$y_i = m(t_i) + \varepsilon_i$$

Explanation:

yi= Response variable of the i-th observation
ti= Predictor variable of the i-th nonparametric component observation
m= Unknown regression function
εi= Residual of the i-th observation

2.7 Semiparametric Regression

Semiparametric regression is a combination of parametric and nonparametric regression (Ruppert, 2003). In semiparametric regression, it contains both parametric and nonparametric regression components. The parametric regression component is known to have variables with a patterned curve. Meanwhile, the nonparametric regression component has variables whose curve shapes are unknown. The following is the model of semiparametric regression as follows:

$$y_i = \beta_0 + \beta_1 x_1 + f(t_i) + \varepsilon_i \, , i = 1,2,3, \dots \, , n$$

$Y = \mathrm{X}\mathbf{Q} + \boldsymbol{f} + \boldsymbol{\varepsilon}$
Explanation:
yi = Response variable from the i-th data
$\beta 0$, $\beta 1$ = Parameters
xi = Predictor variable from the i-th data for the parametric component
$f(ti)$ = Regression function of unknown form for the nonparametric component
ti = Predictor variable from the i-th data for the nonparametric component
εi = i-th error assumed to be distributed ~ N (0, $\sigma 2$)

From the model above, there is a parametric component, which is $\beta 0 + \beta 1 x 1$, and a nonparametric component, which is $f(ti)$ (Ruppert, 2003). If written in matrix form, it would be as follows:

$$Y = \mathrm{X}\mathbf{Q} + \boldsymbol{TM} + \boldsymbol{\varepsilon}$$

2.8 Karnel's Return

Kernel regression is a nonparametric statistical technique that used to estimate the function m(x) which is present in the model nonparametric regression. Nadaraya and Watson in 1994 defined the kernel regression estimator, which is called the Nadaraya-Watson estimator (Hardle, 1994). There are seven smoothing techniques that can be used, namely histogram, kernel, orthogonal series, spline, k-NN, Fourier series, and wavelet (Eubank, 1998). The kernel estimator is a nonparametric approach to estimating a smooth curve. The kernel estimator is an extension of the histogram estimator introduced by Rosenblett (1956) and Parzen (1962), hence it is called the Rosenblett-Parzen kernel density (Hardle, 1994).

$$K_h(x) = \frac{1}{h} K\left(\frac{x}{h}\right), \text{untuk } -\infty < x < \infty, \; h > 0$$

And also fulfilling:

$K(x) \geq 0$, for all x

$$\int_{-\infty}^{\infty} K(x)dx = 1$$

$$\int_{-\infty}^{\infty} x^2 K(x)dx = \sigma^2 > 0$$

$$\int_{-\infty}^{\infty} xK(x)dx = 0$$

Research Methodology

The methodology of this research uses a quantitative approach with a simulation-based

experimental design to analyse the queuing process in the distribution of post-flood disaster relief. This research aims to identify and measure the efficiency of the aid distribution system by using parametric regression methods to model the relationships between variables that affect waiting times and queues. The data used in this research is sourced from simulations of aid distribution scenarios in flood-affected areas, which include variables such as the number of aid recipients, service time, and distribution capacity. The researchers will use simulation software such as Arena Simulation or MATLAB to build a queue model that replicates real-life situations in aid distribution.

In the data collection stage, researchers will utilise secondary data obtained from government reports, humanitarian agencies, and related organisations regarding aid distribution during flood disasters. This data includes the distribution service time, the number of aid recipients, and the number of available aid posts. Next, a parametric regression model will be applied to identify the relationship between factors affecting the speed of the distribution process and the satisfaction level of aid recipients. The model validity test is conducted by comparing the simulation results with existing historical data to ensure that the constructed model can reflect the reality of the post-disaster aid distribution system.

Data analysis will be conducted using linear regression or parametric logistic regression techniques, depending on the data distribution and the type of variables used. Hypothesis testing is conducted to assess whether certain factors, such as the number of aid posts and service time, significantly affect waiting time in the queue system. The results of this analysis are expected to provide insights on how to improve the efficiency of post-flood disaster aid distribution. The researchers will also ensure that all research procedures comply with research ethics principles, especially regarding the use of sensitive data related to the welfare of the affected communities.

Results

This Parametric Regression Method is used to see how long the process takes in a queue, and to calculate it, you can refer to the example below. To perform calculations using parametric regression based on the given data, we can conduct several analyses, assuming that we are trying to model the relationship between the arrival time variable (X) and the service time variable (Y) using linear regression. In this case, linear regression is a parametric regression method.

Table 3.1 Arrival Times

Queue Number	Sender To	Arrival Time (X)	Service Time (Y)
A	1	3	9
B	2	8	20
C	3	13	4
D	4	14	8
E	5	17	12

Parametric linear regression models the relationship between two variables with the equation:

$$Y = \beta_0 + \beta_1 X$$

Where:
Y is the service time,

X is the arrival time,
β_0 is the intercept,
β_1 is the regression coefficient (slope of the line).

Next, the calculation process is carried out according to the Regression Coefficients (β0 and β1). The regression coefficients β1 and β0 can be calculated using the following formulas:

$$\beta_1 = \frac{n\sum X_i Y_i - \sum X_i \sum Y_i}{n\sum X_i^2 - (\sum X_i)^2}$$

$$\beta_0 = \frac{\sum Y_i - \beta_1 \sum X_i}{n}$$

Compiling Manual Calculations by inputting all components to find β1 and β0
Count:

$$\sum Y_i, \sum X_i^2, \text{ dan } \sum X_i Y_i:$$

$$\sum Y_i = 9 + 20 + 4 + 8 + 12 = 53$$

$$\sum X_i^2 = 3^2 + 8^2 + 13^2 + 14^2 + 17^2 = 9 + 64 + 169 + 196 + 289 = 727$$

$$\sum X_i Y_i = 3 \times 9 + 8 \times 20 + 13 \times 4 + 14 \times 8 + 17 \times 12 = 27 + 160 + 52 + 112 + 204 = 555$$

Then, calculate β_1:

$$\beta_1 = \frac{5 \times 555 - 55 \times 53}{5 \times 727 - (55)^2} = \frac{2775 - 2915}{3635 - 3025} = \frac{-140}{610} \approx -0.2295$$

Then, calculate β_0:

$$\beta_0 = \frac{53 - (-0.2295 \times 55)}{5} = \frac{53 + 12.6725}{5} = \frac{65.6725}{5} = 13.1345$$

The next step is to perform a Regression Equation on the processed values with β0 =13.1345 and $\beta_1 = -0.2295$ that the linear regression equation can be written as follows: Y=13.1345−0.2295X.

Conclusion

The conclusion from the linear regression calculations conducted on the arrival time and service time data in the post-flood disaster aid distribution queue system shows a negative relationship between the two variables. Based on the regression results, the linear regression equation Y=13.1345−0.2295X was obtained, which indicates that each additional minute in arrival time will reduce the service time by approximately 0.23 minutes (or about 14 seconds). This indicates that the longer the arrival time of the aid recipients, the faster the time required to serve them. Although this relationship is negative, in this context, it may indicate an adjustment in the distribution system, where service capacity can increase as the number of recipients arriving simultaneously grows.

It is important to note that the intercept (13.1345) in the regression equation indicates the estimated service time when the arrival time is 0 minutes, although this is not practical in a real-world context. Nevertheless, this value provides an indication of the amount of service time required under initial conditions without any recipients arriving. The value of the regression coefficient β1=−0.2295 indicates that there is a decrease in service time as the number of aid recipients increases. This may reflect the presence of efficiency mechanisms or adaptations in the aid distribution system that affect service speed when more recipients are present at the same time. Overall, this regression model provides important insights for managing queue systems and post-disaster aid distribution. By using this model, stakeholders can predict service times based on the arrival of aid recipients, allowing for the optimisation of distribution flows and more efficient

resource management. Although this model provides useful results, further research with additional variables or more complex models (such as M/M/c queue models or event-based simulations) may be needed to address greater uncertainty and variability in the aid distribution system, especially in larger-scale disasters.

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