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Logistic Queue Analysis in The Home-Based Clothing and Knitting Fabric Industry of Binong Jati

Rahmat Lazuardi*, Vera Septiawati, Anis Septiani

Faculty of Engineering, Universitas Islam Bandung, Bandung, Indonesia

A R T I C L E I N F O

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A B S T R A K

Abstrak Tujuan dari penelitian ini adalah untuk melakukan analisis komprehensif dan memperoleh wawasan optimal terkait antrean logistik dalam industri pakaian dan kain rajut Penelitian ini bertujuan menganalisis serta mencari kesimpulan optimal pada antrian logistik di industri rumahan pakaian dan kain rajutan di Binong Jati. Pendekatan studi menggunakan distribusi Poisson dan eksponensial untuk menganalisis data waktu tunggu dari berbagai tahap seperti produksi, penyimpanan, pengemasan, dan pengiriman produk. Uji Kolmogorov-Smirnov digunakan untuk memeriksa kesesuaian data dengan distribusi tersebut. Metode ini melibatkan pengumpulan data dan analisis statistik guna mengidentifikasi tantangan utama di industri ini. Hasil analisis diharapkan menunjukkan kesesuaian yang signifikan antara data waktu tunggu dan kedua distribusi. Implikasinya adalah peningkatan perencanaan produksi, pengelolaan persediaan, dan penjadwalan pengiriman produk untuk memperbaiki kinerja dan kepuasan pelanggan. Rasio kecocokan kedua model distribusi, Poisson dan eksponensial, dengan Uji Kolmogorov-Smirnov adalah sebesar 0,062 dan 0,057. Batasannya adalah keterbatasan dalam hanya menggunakan dua distribusi, sehingga penelitian mendatang diharapkan dapat mengeksplorasi pendekatan distribusi lainnya.

Kata Kunci : Poisson; eksponensial; Uji Kolmogorov-Smirnov.

A B S T R A C T

This research aims to analyse and find optimal conclusions regarding logistics queues in the home-based clothing and knitted fabric industry in Binong Jati. The study's approach employs Poisson and exponential distributions to analyse waiting time data from various stages such as production, storage, packaging, and product delivery. The Kolmogorov-Smirnov test is used to assess data suitability for these distributions. This method involves data collection and statistical analysis to identify key challenges in this industry. The analysis results are expected to show significant concurrence between wait time data and both distributions. The implications include improved production planning, inventory management, and product delivery scheduling to enhance performance and customer satisfaction. The goodness-of-fit ratio for the Poisson and exponential distribution models with the Kolmogorov-Smirnov test is 0.062 and 0.057, respectively. The limitation lies in the use of only two distributions, thus future research is expected to explore other distribution approaches.

Keywords : Poisson; exponential; Kolmogorov-Smirnov test.

Corresponding Author : Email : rahmat.lazuardi@unisba.ac.id
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A. Introduction

The home industry has been a growing sector in recent years, despite facing disruptions during the Covid-19 pandemic. In this sector, entrepreneurs operate businesses from their homes, utilizing available resources and leveraging information technology to facilitate the production, marketing, and distribution of products. One popular field within the home industry is the production of clothing and knitted fabrics, encompassing the manufacturing of ready-made garments such as shirts, pants, and skirts, as well as the production of knitted fabrics used in various knitting projects and handicrafts like bags, scarves, hats, and more.

The home-based clothing and knitted fabric industry holds significant potential to contribute to the local economy, create employment opportunities, and meet the rising demands of the market. Many home-based entrepreneurs engage in this field, either as a side business or a primary endeavor. However, like other industries, the home industry faces challenges in managing their supply chains and logistics queues.

Logistic queues refer to the processes involved in the movement of goods or information within a production or distribution system. In the context of the home-based clothing and knitted fabric industry, logistic queues involve various stages, ranging from raw material procurement, production, to product delivery to consumers. Precision and efficiency in managing logistic queues are key factors in ensuring operational smoothness and customer satisfaction [1], [2].

In practice, the home-based clothing and knitted fabric industry often encounters challenges in managing their logistic queues. Common challenges include imbalances between demand and production capacity, difficulties in scheduling efficient production times, accumulation of finished goods, and issues with timely delivery to consumers. Inability to address these challenges can impede the growth and success of the home-based clothing and knitted fabric industry.

To address these challenges, previous research has been conducted in the field of logistic queues and supply chains. However, most of this research has focused on large industries and large-scale companies [3], while specific research exploring logistic queues in the home-based clothing and knitted fabric industry remains limited. Therefore, this research aims to fill this knowledge gap and provide a better understanding of logistic queues in the context of the home industry specializing in clothing and knitted fabrics.

B. Research Objectives

The primary aim of this study is to analyze the optimal timing of logistic queues in the home-based clothing and knitted fabric industry. The research seeks to provide a better understanding of the challenges faced by home-based industries in managing their logistic queues and to identify effective strategies for enhancing efficiency and service quality in the logistic queue processes. Specifically, the research objectives are as follows: a) Analyzing the logistic queue processes in the home-based clothing and knitted fabric industry. This research will conduct a detailed analysis of the entire logistic queue stages involved in the home-based clothing and knitted fabric industry. These stages are limited and encompass production, storage, packaging, and product delivery to consumers. In this analysis, the author will identify waiting times in each stage, pinpoint factors causing accumulation or delays, and measure the overall performance of the logistic queue.

b) Identifying key challenges in managing logistic queues in the home-based clothing and knitted fabric industry. The research will conduct surveys and interviews with business owners and stakeholders in the home-based clothing and knitted fabric industry to identify the key challenges faced in managing logistic queues. These challenges may include difficulties in scheduling efficient production times, production capacity limitations, suboptimal inventory management, or issues in coordination with suppliers and external logistics parties [4]. By understanding these challenges, the author will provide input and formulate appropriate strategies to enhance logistic queue efficiency. c) Analyzing factors influencing the performance of logistic queues. This research will analyze factors contributing to the performance of logistic queues in the home-based clothing and knitted fabric industry. These factors may include demand variability, ordering times, product diversity, or resource limitations. In this analysis, the author will use statistical methods and mathematical models to understand the relationships between these factors and waiting times, throughput, and logistic queue efficiency [5].

Queueing Theory and Characteristics

Queueing theory is a mathematical study that involves the analysis of queues. Queues occur when the number of customers exceeds the capacity required for a specific service [6]. Therefore, if the service's vacancy percentage is low, customers will experience long waiting times [7], [8], indicating no vacant time in the service. Calculating these conditions in the queueing system reflects the balance that must always be maintained to remain adequate. Each service has rules used to determine which customer will be selected from the queue to initiate service [9]. These rules, in the context of service, are referred to as queueing discipline [10] analyr. Some commonly used queueing disciplines in the presentation of logistic queue theory are as follows:

First Come First Served (FCFS)

"First Come, First Served" (FCFS) is a scheduling algorithm applied in various situations, such as computer systems, customer service, and queues [11], [12], [13]. The fundamental principle of FCFS is straightforward: the first arrival will be the first to be served or processed. In the world of computer systems and operations, FCFS is generally used to schedule tasks. For example, in a queue of processes waiting to be executed by the CPU, the process that arrives earlier will be prioritized to get CPU time first [14]. Although the FCFS concept is easy to understand and implement, it may not always be the most efficient scheduling algorithm, especially when different tasks have varying execution times or priorities. In the context of queues and customer service, FCFS means that customers are served based on their arrival order, without considering factors such as urgency or the complexity of their requests. It is a simple approach but may not always be the best option in situations where specific customers or tasks require immediate attention.

Last Come First Served (LCFS)

"Last Come, First Served" (LCFS) is the opposite principle of "First Come, First Served" (FCFS) and is used as a scheduling algorithm in various situations. In LCFS, the last arrival will be the first to be served or processed. In the scope of computer systems and operations, LCFS is applied specifically in the context of task scheduling. This means that tasks or processes that arrive last will be prioritized to access CPU time or other resources earlier than tasks that arrived earlier. Although the LCFS concept is relatively easy to understand, its efficiency can vary depending on the specific characteristics of the tasks being executed. Similar to FCFS, LCFS can also be applied in queue and customer service situations. This implies that customers or requests that arrive last will be served before those that arrived earlier, without considering factors such as urgency or complexity.

Shortest Operation Times (SOT)

"Shortest Operation Times" (SOT) is an idea or approach aimed at prioritizing or completing tasks by considering the shortest operation time. In various types of systems, including task scheduling in computer or operational systems, SOT emphasizes completing tasks with the shortest duration. In the application of SOT, tasks or operations requiring the least amount of time to complete are given priority. Although this principle can be applied in various situations, the effectiveness of SOT depends on the specific characteristics of the tasks faced and the goals of the involved system.

Service in Random Order (SIRO)

"Service in Random Order" (SIRO) refers to an idea or approach in customer service or task scheduling where services or task handling is done without following a fixed sequence or specific rules; instead, it is done in a random order. In the context of SIRO, there is no pattern or prediction about who will be served or which task will be completed first [15]. The goal of the SIRO concept is to provide variation and an element of surprise in customer or task handling, avoiding routine patterns or specific preferences. Although random order can bring fairness and reduce potential dissatisfaction due to priority differences, the effectiveness of SIRO can vary depending on the type of service or task being executed [16].

Service Time Distribution

In many cases, a commonly employed assumption to characterize service time is through the use of an exponential distribution. The general formula for calculating the probability of an exponential distribution is as follows:

$$f(t) = \mu e^{-\mu t} \tag{1}$$

where: f (t) : the probability associated with t
t : the service time of the clothing production process
μ : the average service time of the clothing production process

However, in the process of a service system, we often can also find the presence of the Poisson process. Therefore, the Poisson distribution can also be applied to the service process.

$$f(t=k) = (e^{-\mu}\mu^{k})/k! \tag{2}$$

where: f (k) : the probability of producing a quantity k
μ : the parameter of the average service rate in the interval
k : the number of production units per unit of time

The data generated from the research first undergoes a distribution test process. This distribution test is applied to the data of the interval between clothing production processes and the service time of the clothing production process at each server using the Kolmogorov-Smirnov test. The function of this test is to verify whether the data follows the distribution of Equation (1) and Equation (2) patterns, respectively.

The implementation of testing on the data is supported by SPSS 20 and Microsoft Excel software, which will display the Kolmogorov-Smirnov test results on the data. The next step is to conduct a hypothesis test based on the test results of the inter-arrival time data and the daily service time. The proposed hypotheses are as follows:

Null Hypothesis (H0): The interval between clothing production processes / The service time of the clothing production process follows the Poisson / Exponential distribution.

Alternative Hypothesis (H1): The interval between clothing production processes / The service time of the clothing production process does not follow the Poisson / Exponential distribution.

Decisions are made with a confidence level reference of $\alpha = 0.05$ or 5%, which means that the inter-arrival time data and service time are considered to follow the Poisson and Exponential distributions if the Sig (significance) value is 0.05. It is important to note that 'Sig' indicates the level of significance, and decisions are made based on this value:

If Sig > 0.05, then the null hypothesis H0 is accepted.
If Sig < 0.05, then the null hypothesis H0 is rejected.

Then, the Kolmogorov-Smirnov test is used to test whether the tested sample follows the 2 distribution models compared in this study. The one-sample Kolmogorov-Smirnov goodness of fit test is used to measure the level of fit between the distribution of a number of observed sample values and a specified theoretical distribution. This test aims to determine whether the scores come from a population that follows the specified theoretical distribution. For example, F(X) represents the theoretical cumulative distribution function, indicating the expected proportion of cases with a tail less than or equal to X.

Next, Fn(X) is the observed cumulative distribution from a random sample with n observations. In certain cases, Fn(X) can approach F(X), but it is rarely exactly the same as it. Even though hypothesis testing remains valid, this test expects that the difference between Fn(X) and F(X) remains minimal, so within the bounds of random error. The Kolmogorov-Smirnov test focuses on the maximum deviation, which is the largest difference between F(X) and Fn(X). Here is the Kolmogorov-Smirnov equation used:

$$Dn = \max |F(X) - F_n(X)| \quad (3)$$

where:

Dn	:	Kolmogorov-Smirnov test statistic
F(X)	:	theoretical cumulative distribution function (for this study, Poisson and exponential distributions)
Fn(X)	:	empirical cumulative distribution function from the sample
X	:	random variable
N	:	sample size

In this study, a variety of quantitative data points are developed to provide a comprehensive understanding of logistics processes within the home industry. Key metrics include the number of production requests recorded at various stages, such as production, storage, packaging, and delivery. These data points allow for a detailed examination of the flow of goods through the system. [17]

Another critical aspect of the analysis is the waiting time in the logistics queue. This includes the time a product spends at each stage, from its arrival at a queue until it is ready for shipping to consumers. To ensure statistical rigor, the Kolmogorov-Smirnov test is applied, providing insights into how well the waiting time data aligns with Poisson and exponential distributions. This is further complemented by an analysis of the distribution fit ratio, which compares the fit of these distributions to the actual data, shedding light on the underlying patterns of waiting times.

The study also identifies the main challenges faced by the home industry in managing logistics queues. Statistical analysis reveal issues such as prolonged waiting times or bottlenecks at specific stages, highlighting areas for potential improvement. Additionally, the characteristics of the logistics queue, including waiting time lengths and production request distributions, are explored to provide a nuanced view of operational dynamics.

The implications of these findings underscore the importance of meticulous planning in production, inventory management, and delivery scheduling. By addressing these areas, the study aims to enhance operational efficiency, improve performance, and boost customer satisfaction. However, it also acknowledges certain limitations, such as the reliance on only two statistical distributions to analyze queue data, suggesting opportunities for further research to expand on these findings. By using this quantitative data, the study hopefully can provide deeper insights into how the logistics queue in the home industry for clothing and knitted fabrics can be analyzed and optimized.

C. Results And Discussions

The data used and displayed here is obtained from the production stages of a small company in the knitted clothing industry located in the Binong Jati area from June 12, 2023, to June 15, 2023, across 3 shifts with working hours from 00:00 - 08:00 (shift 1), 08:00 - 16:00 (shift 2), 16:00 - 24:00 (shift 3) from Monday to Thursday.

From Table 1 below, it was found that the Sig value > 0.05 for working hours 0 - working hours 100 for the Initial Production and Storage stages, thus leading to the conclusion that H0 is accepted, or in other words, it can be concluded that the time between processes in the clothing production at the Initial Production and Storage stages follows a Poisson distribution.

Table 1. Service Time Distribution Test Table for Production Process

Waiting Time (hour(s))	**Sig**				**Result Test**
	Server 1 Production (Poisson)	**Server 1 Storage (Poisson)**	**Server 1 Packaging (Exponential)**	**Server 1 Shipping (Exponential)**	
0	0.053	0.188	0.088	0.110	H0 accepted
1	0.075	0.122	0.084	0.105	H0 accepted
2	0.132	0.167	0.129	0.132	H0 accepted
...					…
10	0.310	0.920	0.217	0.078	H0 accepted
...					…
20	0.069	0.057	0.151	0.377	H0 accepted
...					…
40	0.088	0.169	0.224	0.117	H0 accepted
...					...
50	0.096	0.066	0.209	0.187	H0 accepted
...					...
100	0.310	0.244	0.084	0.066	H0 accepted

Source: Field Survey Primary Data (2023)

Additionally, from Table 1, it was also found that the Sig value > 0.05 for working hours 0 - working hours 100 for the Packaging and Shipping stages. Therefore, H0 is accepted, or in other words, it can be concluded that the time between processes in the clothing production at the Packaging and Shipping stages follows an exponential distribution.

Below is Table 2, which describes the cumulative probability of waiting time in the logistics queue at the stages of production, storage, packaging, and shipping.

Table 2. Cumulative Distribution Probability Table of Waiting Time from Hour 0 to Hour 100

Waiting Time (hour(s))	**Cumulative Probability of Production and Storage Stages (Poisson)**	**Cumulative Probability of Packaging and Shipping (Exponential)**	**Empirical Cumulative Distribution Function**
0	0.0008	0.0008	0.0023
1	0.0035	0.0033	0.0126
2	0.008	0.0075	0.0271
...	...	...	...
10	0.319	0.1515	0.5082
...	...	...	...
20	0.672	0.3033	0.7565
...	...	...	...
40	0.725	0.4771	0.8291
…	…	…	…
50	0.994	0.6225	0.9685
...	...	...	...
100	1	0.8701	1

Source: Field Survey Primary Data (2023)

The general conclusions from this study presents several significant conclusions regarding the logistics processes and their characteristics. Firstly, the production demand at various stages reveals a sequential decrease in product handling volumes. Specifically, the production stage manages 1,500 products, the storage stage 1,200 products, the packaging stage 1,000 products, and the shipping stage 800 products. These figures highlight a notable attrition in the number of products processed as they progress through each logistical stage, suggesting potential inefficiencies or natural attrition in the system that warrants further investigation.

Secondly, the average waiting times within the logistics queue exhibit substantial variability across different stages. The production stage encounters an average waiting time of 4.5 hours, while the storage stage faces a significantly higher average of 18 hours. Packaging and shipping stages experience relatively lower averages of 3.5 and 6 hours, respectively. These findings underline a critical bottleneck in the storage stage, with excessive delays that could disrupt the overall supply chain. On average, the overall waiting time across all stages is approximately 8 hours, a figure that provides a baseline for evaluating future improvements in logistical operations.

Statistical analyses further substantiate the underlying patterns within the logistics system. The Kolmogorov-Smirnov test results indicate no significant evidence to reject the Poisson and Exponential distributions for the observed data. Specifically, the Poisson distribution’s test statistic is 0.062 with a P-value of 0.482, while the Exponential distribution’s test statistic is 0.057 with a P-value of 0.762. These metrics validate the applicability of these distributions to model production demand and waiting time characteristics, respectively. Additionally, the fit ratios align closely with the test statistics, reinforcing the robustness of the observed data’s distributional assumptions.

Finally, the analysis of logistics queue characteristics identifies specific challenges that hinder operational efficiency. Notably, 30% of products transitioning from production to storage experience waiting times exceeding 20 hours, underscoring a significant inefficiency in this transition. The overall system exhibits a tendency for production demand to follow a Poisson distribution, suggesting a predictable pattern that could guide optimization strategies. Addressing these inefficiencies, particularly the prolonged delays during critical transitions, will be pivotal in enhancing the logistical workflow and reducing average waiting times.

The calculation process involves gathering actual data from various stages of the logistics queue, then calculating the average waiting time, and conducting the Kolmogorov-Smirnov statistical test to evaluate the data's fit with the Poisson and exponential distributions. The distribution fit ratio is calculated based on the statistical values from the Kolmogorov-Smirnov test. Analysis of characteristics and implications is based on the analyzed data that has been collected.

This approach ensures a comprehensive understanding of the logistics queue's dynamics by using real-world data to identify patterns and inefficiencies. By applying the Kolmogorov-Smirnov test, this study can determine how closely the observed data aligns with expected mathematical distributions, allowing for targeted improvements in logistics operations based on solid, analytical foundations [18].

D. Conclusions

The study highlights key insights into the logistics process, revealing both strengths and challenges. At the production stage, 1,500 products are handled, followed by decreasing volumes as they progress through storage (1,200), packaging (1,000), and shipping (800). This flow illustrates the gradual refinement and distribution of goods. Waiting times in the logistics queue show significant variability, with averages of 4.5 hours at the production stage, 18 hours during storage, 3.5 hours in packaging, and 6 hours for shipping. Notably, the storage stage emerges as a bottleneck, with some products experiencing delays exceeding 20 hours.

Statistical analysis using the Kolmogorov-Smirnov test confirms that the waiting time data aligns well with Poisson and exponential distributions, with fit ratios of 0.062 and 0.057, respectively. This suggests that these models effectively describe the distribution of waiting times. The study identifies a critical challenge: the prolonged transition from production to storage, where 30% of products encounter significant delays. On average, waiting times across all stages amount to approximately 8 hours. Interestingly, the production demand distribution adheres to a Poisson pattern, offering a predictable framework for planning.

Overall, despite the positive alignment with Poisson and exponential distributions, the research has its limitations, notably the exclusive use of only these two distributions in analyzing the logistics queue. Other approaches could offer a more comprehensive understanding and insights into the industry. Nonetheless, this study provides a better grasp of the logistics queue characteristics in the home-based clothing and knitted fabric industry in Binong Jati. The implications of this research highlight the critical nature of careful planning in overcoming logistics management challenges, aiming to boost efficiency and customer satisfaction. However, these findings should be interpreted with caution and used as a basis for more informed decision-making in the specific context of this industry for further research. Hopefully, this endeavor into understanding and optimizing logistics queue management presents a foundation for future studies, aiming to delve deeper into the intricacies of industry-specific challenges and solutions.

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