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Optimizing Production Quantities of Perishable Products Based on Demand Patterns Using Time Series Analysis and the Newsboy Problem at Muun Donuts Lhokseumawe

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Abstract

Muun Donuts in Lhokseumawe is a producer of fresh donuts (a perishable product) that faces daily operational challenges in the form of unpredictable fluctuations in daily demand. The lack of a standard numerical benchmark for determining daily production capacity creates the risk of dual losses, such as waste of raw materials (overstock) and loss of potential profit (stockout). The objective of this study is to determine the optimal production volume and predict the expected maximum profit. This study integrates a time series forecasting approach with the newsboy problem method. The results show that the optimal single-base production quantity for the company is 24,550 pcs. The distribution of optimal production allocation per period throughout 2026 ranges from 23,902 pcs to 25,199 pcs per month, equivalent to an average daily dough conversion of 14 kg to 16 kg per day. Aggregately, the implementation of this proposed integrated method is projected to generate a total expected profit of IDR 1,119,489,296 per year, or yield an annual total profit increase of IDR 25,914,296 compared to the company's current policy. This stochastic approach has proven effective as a foundation for management's tactical decisions to reduce food waste while maintaining the quality of customer service.

Keyword: *perishable product, time series forecasting, newsboy problem, expected profit*

Abstrak

Toko Muun Donuts Lhokseumawe merupakan produsen donat segar yang *(perishable product)* tantangan operasional harian berupa fluktuasi permintaan harian yang tidak pasti. Ketiadaan standar baku numerik dalam penentuan kapasitas produksi harian memicu munculnya risiko kerugian ganda, seperti pemborosan bahan baku *(overstock)* maupun kehilangan potensi keuntungan *(stockout)*. Tujuan penelitian ini adalah untuk menentukan kuantitas volume produksi optimal serta memprediksi nilai keuntungan maksimal yang diharapkan *(expected profit)*. Penelitian ini mengintegrasikan pendekatan *time series forecasting* dengan metode *newsboy problem*. Hasil penelitian menunjukkan kuantitas produksi dasar tunggal yang optimal bagi perusahaan adalah sebesar 24.550 pcs. Distribusi alokasi produksi optimal per periode sepanjang tahun 2026 berkisar antara 23.902 pcs hingga 25.199 pcs per bulan, atau setara dengan konversi rata-rata adonan harian sebanyak 14 kg sampai 16 kg per hari. Secara agregat, implementasi integrasi metode usulan ini diproyeksikan mampu menghasilkan total *expected profit* sebesar Rp1.119.489.296 per tahun, atau memberikan efisiensi peningkatan profit total tahunan sebesar Rp25.914.296 dibandingkan dengan kebijakan aktual perusahaan. Pendekatan stokastik ini terbukti efektif menjadi landasan keputusan taktis manajemen dalam menekan *food waste* sekaligus menjaga kualitas pelayanan pelanggan.

Kata Kunci: *produk mudah rusak, peramalan deret waktu, newsboy problem, keuntungan diharapkan*

1. Introduction

The food industry is one of the sectors most vulnerable to losses resulting from a mismatch between production volume and actual market demand [1]. Food products with a short shelf life, such as donuts, bread, and similar baked goods, cannot be stored for sale the following day because they undergo a significant decline in quality [2]. Determining the optimal production volume for products with a short shelf life has long been a primary focus in the fields of engineering and industrial management [3], [4]. Mismatches between production and demand pose a dual risk of loss for businesses, waste of raw materials due to overproduction (overstock) on one hand, and lost potential profits due to underproduction (stockout) on the other.

Various previous studies on bakery products have shown that integrating time series forecasting methods with a single-period probabilistic inventory model effectively mitigates the risk of losses due to demand fluctuations in perishable products [5], [6]. The Newsboy Problem model, in particular, has proven capable of determining the most profitable production quantity by simultaneously accounting for two risks: losses due to overproduction (overage cost) and underproduction (underage cost), based on the probability distribution of demand [7], [8]. However, the accuracy of this model heavily depends on precise demand estimates, making time series forecasting based on historical data a crucial component in establishing a structured, data driven production decision-making framework [9], [10].

Muun Donuts in Lhokseumawe is a food business that produces fresh donuts without preservatives, meaning the products are only suitable for consumption on the day they are made. Based on historical sales data for the period January-December 2025, this shop faces wide daily fluctuations in demand; for example, in April the difference between the highest and lowest demand reached 230 pieces/day (950 pieces/day to 720 pieces/day), while in December it reached 150 pieces/day (930 pieces/day to 780 pieces/day). The absence of a standard numerical benchmark for determining daily production capacity means that production decisions still rely on the manager's subjective estimates, thereby risking double losses in the form of raw material waste and lost potential profits.

Based on these issues, this study aims to: (1) determine the optimal production quantity for donuts at Muun Donuts in Lhokseumawe by integrating a time series forecasting approach with the newsboy problem method, and (2) predict the maximum expected profit from implementing this optimal production quantity.

2. Material and Methods

This research was conducted at Muun Donuts Lhokseumawe, located on Jl. Merdeka Barat, Banda Sakti Sub-district, Lhokseumawe City, starting in January 2026. The data used are the historical production and sales records of donuts for the period January-December 2025, as presented in **Table 1**.

Table 1. Donut Production and Sales Data, January-December 2025

Period	Production Quantity (pcs)	Units Sold (pcs)
January	23,375	23,250
February	20,900	20,740
March	25,575	25,335
April	27,225	27,200
May	24,200	23,960
June	24,750	24,550
July	23,100	22,930
August	25,025	24,890
September	22,825	22,800
October	23,650	23,570
November	22,000	21,900
December	28,050	27,980
Total	**290,675**	**289,105**

Source: Muun Donuts Lhokseumawe (2025)

Primary data were obtained through direct observation and unstructured interviews with the store manager, comprising daily production data, sales data, unit production cost, and selling price. Secondary data were obtained from a literature review on perishable products, time series methods, and the newsboy problem. The operational variables used in this study are summarized in **Table 2**.

Table 2. Operational Variables Used in the Study

Variable	Operational Definition
Daily production data	Daily quantity of donut dough produced during the study period, measured in kilograms.
Sales data	Quantity of product actually sold during the study period, used to identify the gap between production and sales.

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Variable	Operational Definition
Excess stock data	Quantity of unsold donuts remaining at the end of the production day, used to calculate the loss incurred.
Unit production cost	Total production cost per unit of donut during the study period.
Selling price	Price obtained from the sum of unit production cost and overhead cost.
Scrap value	Residual value of unsold donut products during the study period.

Data Analysis Procedure

Data analysis was carried out through the following sequential steps:

1. Analyze donut sales data for the period January-December 2025 to identify the underlying seasonal demand pattern.
2. Compute demand forecasts using the time series method(s) appropriate to the identified data pattern, namely the quadratic, exponential, and cyclic methods.
3. Evaluate the forecasting results by calculating the error value (MSE, SEE, MAPE) for each method.
4. Select the forecasting method with the smallest error value to be used for predicting demand in the subsequent period.
5. Compute the unit cost, selling price, and scrap value of the product.
6. Compute the cumulative probability of the product.
7. Compute the optimal production quantity using the critical ratio.
8. Compute the expected profit using the newsboy problem method to determine the optimal expected profit.
9. Compute the difference between the expected profit and the profit obtained under the company's actual (non-optimized) policy.

Demand Forecasting

Based on the pattern of the historical data, which contains both trend and seasonal components, three time series methods were tested: the quadratic, exponential, and cyclic methods, with the general equations $Y'=a+bt+ct^2$, $Y'=ae^{bt}$, and $Y'=a+b\sin\left(\frac{2\pi t}{n}\right)+c\cos\left(\frac{2\pi t}{n}\right)$ respectively. The accuracy of each method was evaluated using the Mean Square Error (MSE), Standard Error of Estimate (SEE), and Mean Absolute Percentage Error (MAPE) as follows [11], [12]:

$$MSE=\frac{\sum(Y-Y')^2}{n}$$

$$SEE=\sqrt{\frac{\sum(Y-Y')^2}{n-f}}$$

$$MAPE=\frac{\sum|PE_t|}{n}$$

$$PE_t=\left(\frac{Y-Y'}{Y}\right)\times 100\%$$

where Y is the actual demand value, Y' is the forecast value, n is the number of data points, and f is the number of degrees of freedom used by the fitted model. The method with the smallest error value was selected as the best forecasting model and was then verified using a Moving Range Chart, with upper and lower control limits of ±2.66 MR, to confirm that the forecast was representative of the data.

Newsboy Problem

The second stage applied the newsboy problem method to determine the optimal production quantity and the expected profit [13], [14]. The optimal production quantity (Qo) was determined based on the critical ratio (CR), which compares the cumulative probability of demand with the cost ratio as follows:

$$Prob(D\le Q_o)<CR<Prob(D\le Q_o+1),\ where\ CR=\frac{UC-SV}{SP-SV}$$

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where UC is the unit cost, SP is the selling price, and SV is the scrap value. The expected profit (EP) at the optimal production quantity is then calculated using the equation:

$$EP(Q)=D\times SP+(Q-D)\times SV-Q\times UC, \quad Q>D$$

The monthly optimal production quantity was obtained by proportionally distributing the forecast result for each period against the single base production quantity, while the effectiveness of the method was measured from the difference between the expected profit and the company's actual profit.

3. Results and Discussion

Demand Forecasting

The distribution pattern of donut sales data for the period January-December 2025 showed a combination of trend and seasonal patterns, so three time series methods were tested: quadratic, exponential, and cyclic. The fitted equation obtained for each method is presented in **Table 3**.

Table 3. Fitted Time Series Forecasting Equations

Forecasting Method	Fitted Equation
Quadratic	$Y' = 23457{,}6149 + (89{,}0672)t + (1{,}0252)t^2$
Exponential	$Y' = 2{,}3e^{0{,}00414351t}$
Cyclic	$Y' = 24{,}092.08 + 545.80 \sin(2\pi t/n) - 327.82 \cos(2\pi t/n)$

Source: Processed data

The recapitulation of the error values for each fitted equation is presented in Table 4.

Table 4. Recapitulation of Forecasting Error Values

Forecasting Method	MSE	SEE	MAPE
Quadratic	5712119,497	2759,738	0,0892
Exponential	3816750,35	2140,119	0,0651
Cyclic	3732908,559	2230,966	0,0603

Source: Processed data

Based on **Table 4**, the cyclic method produced the smallest error values for the MSE and MAPE criteria, and was therefore selected as the demand forecasting model for donuts for the period January-December 2026. Verification using a Moving Range Chart with upper and lower control limits of ± 6,526.67 showed that all data points fell within the control limits, confirming that the cyclic forecast function in Table 3 is representative and suitable for use. The demand forecast for donuts for the period January–December 2026 is presented in **Table 5**.

Table 5. Demand Forecast Results for Donuts, January-December 2026

Period	Forecast Result (pcs)
January 2026	24081
February 2026	24401
March 2026	24638
April 2026	24729
May 2026	24649
June 2026	24420
July 2026	24103
August 2026	23783
September 2026	23546
October 2026	23456
November 2026	23535
December 2026	23764
Total	289105

Source: Processed data

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Optimal Production Quantity

The optimal production quantity was determined using the newsboy problem method with a unit cost of IDR 3,200/pcs, a selling price of IDR 7,000/pcs, and a scrap value of IDR 0/pcs, since unsold products on the day of production have no resale value. The cumulative probability of the historical production and sales data used to determine the critical ratio position is presented in **Table 6**.

Table 6. Cumulative Probability of Donut Production and Sales

Production (pcs)	Sales (pcs)	Sold Probability	Cumulative Probability
23.375	23.250	0,995	0,083
20.900	20.740	0,992	0,166
25.575	25.335	0,991	0,249
27.225	27.200	0,999	0,333
24.200	23.960	0,990	0,416
24.750	24.550	0,992	0,499
23.100	22.930	0,993	0,582
25.025	24.890	0,995	0,666
22.825	22.800	0,999	0,749
23.650	23.570	0,997	0,833
22.000	21.900	0,995	0,916
28.050	27.980	0,998	1

Source: Processed data

The critical ratio obtained was CR = (3,200 − 0) / (7,000 − 0) = 0.457. Based on Table 6, this CR value falls between the cumulative probability at a quantity of 23,960 pcs (0.416) and 24,550 pcs (0.499), so the single base optimal production quantity was set at 24,550 pcs. This quantity was then proportionally distributed against the forecast for each month to obtain the optimal production quantity for the period January-December 2026, as presented in **Table 7**.

Table 7. Optimal Donut Production Quantity, January-December 2026

Period	Forecast (pcs)	Optimal Production (pcs)
January 2026	24081	24539
February 2026	24401	24865
March 2026	24638	25105
April 2026	24729	25199
May 2026	24649	25118
June 2026	24420	24884
July 2026	24103	24561
August 2026	23783	24235
September 2026	23546	23994
October 2026	23456	23902
November 2026	23535	23982
December 2026	23764	24216
Total	289105	294600

Source: Processed data

Expected Profit

The expected profit calculated using the optimal production quantity in **Table 7** is compared with the company's actual profit for the corresponding period of the previous year in **Table 8**.

Table 8. Recapitulation of Expected Profit for Donuts, January-December 2026

Period	Production/Month (kg)	Production/Day (kg)	Actual Profit (IDR)	Expected Profit (IDR)	Difference (IDR)
January	446,16	14.39	87,950,000	93,248,658	5,298,658
February	446,164	16.14	78,300,000	94,487,464	16,187,464
March	452,091	16.15	95,505,000	95,403,268	-101,732
April	456,473	14.73	103,280,000	95,756,670	-7,523,330
May	456,691	14.73	90,280,000	95,448,869	5,168,869
June	452,436	15.08	92,650,000	94,559,664	1,909,664
July	446,564	14.41	86,590,000	93,332,258	6,742,258
August	440,636	14.21	94,150,000	92,093,452	-2,056,548
September	436,255	14.54	86,560,000	91,177,648	4,617,648
October	434,582	14.02	89,310,000	90,828,046	1,518,046
November	436,036	14.54	82,900,000	91,132,047	8,232,047
December	440,291	14.20	106,100,000	92,021,252	-14,078,748
Total	5356,382	176.27	1,093,575,000	1,119,489,296	25,914,296

Source: Processed data

Overall, the total projected expected profit for 2026 is IDR 1,119,489,296, representing an increase of Rp25,914,296 (equivalent to 2.37%) compared to the company's actual total profit of IDR 1,093,575,000 for the same period the previous year. The optimal daily dough production range is between 14 kg and 16 kg, which can serve as a practical guideline for managers in determining daily production volumes.

Although the proposed method yields an increase in profit on an aggregate basis, its application during certain periods, such as March, April, August, and December actually results in lower expected profit compared to actual profit. This occurs because these periods experience extreme spikes in actual demand, meaning that the optimal production quantity based on the critical ratio is unable to accommodate the full potential demand. Therefore, during periods indicating high demand spikes, managers are advised to relax production limits and adjust production workforce readiness to minimize potential lost sales without compromising the principle of prudence regarding the risk of excess inventory. The integrated approach combining time series and the newsboy problem applied in this study aligns with developments in forecasting-based inventory models for perishable goods, including opportunities for further development using machine learning approaches to improve the accuracy of demand estimates in future research [15].

4. Conclusion

Based on the results of this study, it can be concluded that: (1) the optimal donut production quantity at Muun Donuts Lhokseumawe for the period January-December 2026 ranges from 23,902 to 25,199 pcs per month, with a single base optimal production quantity of 24,550 pcs based on a critical ratio of 0.457 and (2) the application of the integrated time series forecasting and newsboy problem methods is projected to generate a total expected profit of IDR 1,119,489,296 per year, representing a profit-efficiency improvement of IDR 25,914,296 (2.37%) compared with the company's actual production policy. The optimal daily dough conversion of 14 to 16 kg further provides management with a concrete, data-driven production benchmark. This stochastic approach thus proves effective as a tactical management decision basis for reducing food waste while maintaining customer service quality, and it can be extended in future work toward a multi-item, multi-period decision framework with dynamic cost parameters.

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6. Abbreviations

MSE	Mean Square Error
SEE	Standard Error of Estimate
MAPE	Mean Absolute Percentage Error
CR	Critical Ratio
%	Percentage

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