MULTI-COMMODITY INVENTORY MODEL FOR FREE NUTRITIOUS FOOD PROGRAMS BASED ON ECONOMIC ORDER QUANTITY, JUST-IN-TIME, AND REORDER POINT: A CASE STUDY OF GUNUNG SINDUR DISTRICT

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Abstract

The Free Nutritious Meal Program (MBG) requires efficient inventory management due to its routine distribution schedule and the involvement of food commodities with different shelf lives. This study evaluates MBG inventory management at the Nutrition Fulfillment Service Unit (SPPG) level in Gunung Sindur District using a multi-commodity framework based on Economic Order Quantity (EOQ), Just-in-Time (JIT), Reorder Point (ROP), and Safety Stock (SS), including an assessment of cold storage for vegetable commodities. A deterministic quantitative approach is applied, assuming a daily demand of 42,467 meal portions over 240 operational days per year. Rice and eggs are managed using EOQ with ROP and SS, while vegetables are analyzed under JIT and EOQ with cold storage. The results show annual distribution costs of IDR 399 million for rice and IDR 153 million for eggs. JIT-based vegetable distribution incurs the highest cost at IDR 720 million per year. Although cold storage reduces vegetable distribution costs to IDR 480 million per year, additional cold storage costs of IDR 529.2 million increase total system costs from IDR 1.272 billion (without cold storage) to IDR 1.561 billion (with cold storage). As of January 2026, only six of eight SPPG units are operational, serving 21,575 beneficiaries, indicating that at least 12 SPPG units are required to meet full MBG demand.

Keywords: Economic Order Quantity (EOQ); Free Nutritious Meal Program (MBG); Just-in-Time (JIT); Nutrition Fulfillment Service Unit (SPPG); Reorder Point (ROP).

INTRODUCTION

Background

The Free Nutritious Meal Program (MBG) is a strategic government policy aimed at improving the population's nutritional quality, particularly among vulnerable age groups, through routine, planned, and measurable distribution of food that meets nutritional standards. The program serves not only as a public health intervention but also as an instrument to enhance human resource quality and students' learning productivity (Maulana et al., 2025; Tambunan et al., 2025; Merlinda & Yusuf, 2025). The MBG program is implemented through Nutrition Fulfillment Service Units (SPPG), which function as operational units responsible for food inventory management, distribution processes, and direct service delivery to beneficiaries. The program's success highly depends on the efficiency of inventory management systems at the SPPG level, given that the commodities involved have different shelf lives and demand patterns that are routine but subject to potential fluctuations (Nomleni et al., 2025).

Logistics and Inventory Management Issues in the MBG Program

The logistics management of the MBG Program involves multiple food commodities with distinct characteristics, particularly in terms of shelf life, inventory control requirements, and distribution patterns. To simplify the analysis, this study focuses on three main commodities most commonly used in MBG menus: rice, eggs, and vegetables. These commodities exhibit different storage durability levels and logistical implications, making them representative of key challenges in MBG inventory management. Rice, with a long shelf life, is suitable for management using the EOQ model to establish cycle stock. Eggs have a medium shelf life and are more sensitive to supply disruptions, requiring tighter inventory control through a combination of EOQ with Reorder Point (ROP) and Safety Stock (SS). SS is defined as a fixed inventory buffer determined based on daily demand and lead time to prevent stockouts at the SPPG level (Situmorang & Agustin, 2022). In contrast, vegetables are highly perishable and are generally managed through daily distribution based on a Just-in-Time (JIT) approach to maintain food quality (Sukosyah et al., 2023; Machmudin & Safitri, 2020). The implementation of cold storage at the SPPG level can extend the shelf life of vegetables and reduce distribution frequency. However, it also introduces significant operational costs, particularly related to energy consumption and facility maintenance (Masudin et al., 2021; Komathi & Balakisnan, 2024; Azharudin & Basri, 2024). Therefore, MBG logistics management requires a quantitative analysis comparing various EOQ, JIT, and cold storage scenarios to determine efficient and sustainable inventory policies (Nomleni et al., 2025; Suherman et al., 2025).

Characteristics of the Study Area

This study was conducted in Gunung Sindur Subdistrict, Bogor Regency, covering an area of approximately 44.7 km² and administratively divided into 10 villages (Fadhilah et al., 2022; Martana et al., 2021). According to BPS data, the population of Gunung Sindur in 2025 reached 128,867 inhabitants, with children and adolescents forming a large portion. The population aged 0–19 years amounted to 42,467 individuals (BPS Kabupaten Bogor, 2025), representing the potential daily number of MBG beneficiaries. The MBG Program in this area is primarily focused on the education sector. Gunung Sindur Subdistrict has 136 schools serving as MBG service points, unevenly distributed across villages (BPS Kabupaten Bogor, 2025). This results in variations in distribution distances, differences in beneficiary numbers, and unequal operational workloads among SPPG units. The regional characteristics—including service area size, population density, and heterogeneous school distribution—make Gunung Sindur Subdistrict relevant for examining MBG logistics and inventory management issues. These spatial variations require inventory and distribution management systems that are both cost-efficient and adaptive to differences in demand and service intensity.

Research Objectives and Contributions

This study aims to analyze and evaluate inventory management in the MBG Program in Gunung Sindur Subdistrict using a multi-commodity inventory modeling approach that accounts for food characteristics, shelf-life constraints, storage capacity, and operational conditions at the SPPG level. The study focuses on:

1. Inventory policies for rice and eggs using the EOQ model combined with ROP and SS.
2. Vegetable distribution policies by comparing the JIT approach with EOQ under cold storage implementation.
3. Calculating and comparing distribution and total logistics system costs under various inventory management scenarios.
4. Analyzing existing conditions and the required number of SPPG units in relation to service capacity and beneficiary targets.

The contributions of this study are threefold: methodological (development of a multi-commodity inventory model integrating EOQ, JIT, and ROP under shelf-life constraints and SS policies), empirical (quantitative analysis using local data), and practical/policy-oriented (recommendations for inventory management and SPPG capacity planning to support MBG sustainability).

LITERATURE REVIEW

Inventory Management Models in Food Programs

Inventory models such as Economic Order Quantity (EOQ), Just-in-Time (JIT), and Reorder Point (ROP) are widely applied in food logistics to reduce storage costs and prevent stockouts at service units (Aziza et al., 2025; Hardiyanti et al., 2025; Novanto, 2023). EOQ is effective for food commodities with relatively long shelf lives, such as rice, while JIT is more suitable for fresh commodities requiring timely replenishment to maintain quality (Mariani & Ibnas, 2022; Sukosyah et al., 2023; Machmudin & Safitri, 2020). Fresh vegetables, being highly perishable, require cold storage facilities at the SPPG level to extend shelf life and reduce distribution frequency (Masudin et al., 2021; Komathi & Balakisnan, 2024). Integrating EOQ with cold storage can reduce logistics costs by 15–20%, although it increases operational costs related to electricity and maintenance (Azharudin & Basri, 2024; Wardhani & Sukmono, 2024).

Application of Multi-Commodity Inventory Models

The selection of inventory models for MBG programs must consider commodity characteristics, storage capacity, and distribution cost efficiency to ensure operational and financial sustainability (Suherman et al., 2025).

Combining EOQ, JIT, and ROP with Safety Stock policies enables service units to manage multiple commodities efficiently, addressing differences in shelf life, perishability, and demand patterns.

Previous studies have demonstrated that multi-commodity inventory models, especially when integrated with cold storage solutions, improve cost-efficiency and reduce stockouts in government food programs (Azharudin & Basri, 2024; Masudin et al., 2021). These approaches also allow planners to balance operational sustainability with the nutritional objectives of the programs.

METHOD

Research Design and Analytical Framework

This study adopts a deterministic quantitative approach to optimize food inventory systems using mathematical models (Triagustin & Himawan, 2022); Mariani & Ibnas, 2022). This approach enables a measurable analysis of the relationships among demand, storage capacity, and distribution frequency (Oktavia & Natalia, 2021). The analytical framework is formulated as a multi-commodity inventory model that integrates EOQ, JIT, ROP, and deterministic SS, with distribution cycles rounded to full-day units to reflect field-level operational practices (Ginting et al., 2022; Shofiyulloh & Sari, 2025). This study also compares two vegetable management scenarios, namely without and with the implementation of cold storage, to evaluate their impacts on distribution costs, total system costs, and MBG logistics efficiency (Li et al., 2024; Feng et al., 2023; Yin & Tian, 2022). Previous studies indicate that cold storage can reduce fresh product spoilage rates by up to 25%, albeit at the expense of increased electricity costs (Li et al., 2024; Feng et al., 2023). Therefore, its integration with EOQ and JIT strategies is crucial in MBG supply chain management (Sulistyo et al., 2023). The analytical framework is designed as a systematic research workflow, as illustrated in Figure 1, starting with a literature review and problem formulation, followed by the collection and processing of demographic, SPPG, and MBG food demand data. The process continues with inventory modeling and logistics cost analysis, and concludes with the derivation of conclusions and policy recommendations.

Figure 1. Research Workflow Diagram

MBG Logistics System

The MBG logistics system in this study is modeled using a decentralized warehouse concept based on SPPG units, where each SPPG is assumed to operate a single main warehouse with an area of approximately 24 m² as a storage facility prior to distribution to beneficiaries. The warehouse is used to store three main commodities, namely rice, eggs, and vegetables, which differ in terms of shelf life and inventory control requirements (Mukti & Pradana, 2022). The decentralized, SPPG-based warehousing approach is adopted to enhance distribution flexibility, reduce travel time to service points, and align logistics strategies with spatial conditions and the distribution of MBG beneficiaries. This system allows adjustments in storage capacity, shipment size, and distribution frequency according to the operational level and number of beneficiaries at each SPPG, thereby making distribution patterns more adaptive to local demand variations (Ginting et al., 2022; Saffanah et al., 2025). The distribution flow is modeled in a tiered manner, starting from main suppliers to SPPG warehouses based on commodity-specific inventory policies, followed by distribution from SPPG warehouses to schools and MBG service points according to daily operational schedules. All transportation activities are assumed to use vehicles with a maximum capacity of 4 tons per trip, with costs already including loading and unloading activities, and are conducted on effective operational days without considering holidays. This logistics system is designed to balance distribution cost efficiency, delivery timeliness, and the quality of food commodities received by beneficiaries.

Number of Potential MBG Beneficiaries

The determination of daily MBG requirements in this study is based on the number of potential beneficiaries in Gunung Sindur Subdistrict. The primary MBG beneficiaries are assumed to belong to the 0–19 age group, which constitutes the main target population of the program, while other beneficiary groups are assumed to be relatively small and do not significantly affect aggregate daily demand. Based on demographic data for Gunung Sindur Subdistrict, the population aged 0–19 years is recorded at 42,467 individuals. Assuming that each beneficiary receives one MBG portion per operational day, the potential MBG demand is set at 42,467 portions per day. This value is used as the daily operational demand and serves as the basis for all calculations of food requirements, inventory policies, and logistics cost analyses in this study. The spatial distribution of potential MBG beneficiaries is illustrated in Figure 2, while the estimated number of beneficiaries by village is presented in Table 1.

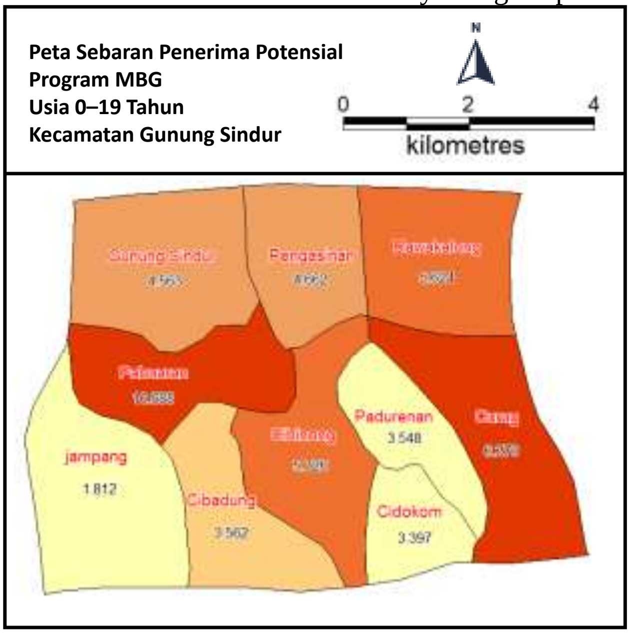

Figure 2. Spatial Distribution Map of Potential MBG Beneficiaries Aged 0–19 Years

This figure illustrates the distribution of potential MBG beneficiaries aged 0–19 years across villages in Gunung Sindur Subdistrict, which serves as the basis for SPPG service capacity planning and spatially based food distribution arrangements.

Table 1. Population and Estimated MBG Beneficiaries Aged 0–19 Years by Village

No	Village	Total Population	Population (0–19 Years)
1	Cibadung	10.796	3.558
2	Cibinong	17.356	5.724
3	Cidokom	10.296	3.394
4	Curug	18.977	6.257
5	Gunung Sindur	13.824	4.558
6	Jampang	5.508	1.815
7	Pabuaran	10.688	3.511
8	Padurenan	10.254	3.380
9	Pengasinan	14.124	4.653
10	Rawakalong	17.044	5.617
Total		**128.867**	**42.467**

Source: BPS Kabupaten Bogor (2025), authors' processing.

Table 1 shows that potential MBG beneficiaries are unevenly distributed across villages, with the largest burdens concentrated in Curug, Cibinong, and Rawakalong Villages. This spatial variation provides an important basis for SPPG capacity planning and spatially based food distribution arrangements.

Daily Demand Data and Model Parameters

Number of Portions and MBG Operational Days

The number of MBG recipients is set at 42,467 portions per day, assuming one portion per beneficiary per operational day. The program is assumed to operate for 240 days per year, following the academic calendar.

Standard Food Requirements per MBG Portion

The standard food requirements per MBG portion are used as the basis for converting the number of portions into daily and annual food requirements, as presented in Table 2.

Table 2. Standard Food Requirements per MBG Portion

Commodity	Unit per Portion	Description
Rice	±150 grams	Weight of uncooked rice
Eggs	1 egg (±60 grams)	Average egg weight
Vegetables	±200 grams	Fresh vegetable weight

Daily Food Requirements

Based on the per-portion standards and the number of MBG recipients, daily food requirements are calculated as follows:

a. Rice
   $d_r = 42.467 \times 0{,}15 = 6.370$ kg/day
b. Eggs
   $d_t = 42.467 \times 1$ egg $= 42.467$ eggs/day
   Assuming an average egg weight of 60 grams per egg, the daily egg requirement in terms of weight is:
   $d_t = 42.467 \times 0{,}06 = 2.548$ kg/day
c. Vegetables
   $d_s = 42.467 \times 0{,}20 = 8.493$ kg/day

Annual Food Requirements

Assuming 240 operational days per year, the annual food requirements are calculated as follows:

$$D = d \times 240$$

Table 3. Daily and Annual Food Requirements of the MBG Program

Commodity	Daily Requirement	Annual Requirement
Rice	6,370 kg	1,528,800 kg
Eggs	42,467 eggs (±2,548 kg)	10,192,080 eggs (±611,520 kg)
Vegetables	8,493 kg	2,038,320 kg

Table 3 presents the daily and annual food requirements of the MBG Program for each commodity based on the assumed number of beneficiaries and operational days in this study.

Operational Model Parameters

The operational parameters applied in this study include a delivery lead time of 1 day, a vehicle capacity of 4,000 kg per trip, and a transportation cost of IDR 1,000,000 per vehicle, inclusive of loading and unloading activities. Daily demand is assumed to be constant and deterministic, with no quantity discounts. All parameters are consistently applied in the EOQ, JIT, ROP calculations and in the evaluation of MBG logistics costs.

Inventory Models and Ordering Policies

The inventory models in this study are designed to accommodate differences in the physical and operational characteristics of MBG food commodities, particularly with respect to shelf life, spoilage risk, and distribution patterns. Accordingly, a combination of inventory policies is employed, including EOQ, JIT, and SS and ROP mechanisms as reorder controls. For commodities with relatively long and medium shelf lives, namely rice and eggs, an EOQ model with shelf-life constraints is applied. This model enables the formation of cycle stock to reduce distribution frequency while constraining inventory levels so as not to exceed storage capacity and product durability limits. In contrast, for commodities with very short shelf lives, namely vegetables without cooling technology, a JIT approach is used, whereby deliveries are made daily according to daily demand without the formation of cycle stock. Under the alternative scenario in which vegetables are managed with cold storage, shelf life is extended, allowing the application of EOQ with ROP and SS controls.

EOQ Model Approach

The EOQ model is employed to determine the optimal order quantity that minimizes total inventory costs (Fadilah et al., 2025), which consist of ordering and holding costs, under the assumption of deterministic and constant demand. This model is applied to determine shipment quantities of food commodities from suppliers to SPPG warehouses, particularly for commodities with medium to long shelf lives, such as rice and eggs.

Mathematically, the order quantity is formulated as follows:

$$EOQ = \sqrt{\frac{2DS}{H}}$$

where *D* denotes annual demand, *S* represents the ordering cost per order, and *H* is the holding cost per unit per year.

Determination of SS

The determination of SS in this study adopts a deterministic approach based on a time buffer (in days). This approach is used because daily demand and delivery lead time are assumed to be fixed variables; therefore, demand and lead time variability are not considered in the applied model. SS is defined as an inventory buffer intended to anticipate potential short-term distribution delays, operational imperfections at the village-level warehouses, and timing gaps arising from the rounding of distribution cycles to full-day units.

Mathematically, SS is calculated as:

$$SS = d \times B$$

where *SS* represents SS in kilograms or units, *d* denotes daily demand, and *B* indicates the stock buffer expressed in days.

The buffer stock value (*B*) is set at two days of demand for rice, eggs, and vegetables managed with cold storage. For vegetables without cooling, physical *SS* is not applied due to shelf-life limitations.

Penentuan ROP

ROP is used as a reorder trigger to ensure that replenishment occurs before operational inventory is depleted. ROP is calculated as the minimum inventory level required to meet demand during the lead time while maintaining the buffer stock.

The ROP formulation applied in this study is expressed as follows:

$$ROP = d \times L + SS$$

where *d* denotes daily demand (kg or units per day), *L* represents the delivery lead time (days), and *SS* is the SS expressed in kilograms or units to ensure supply continuity. Under this mechanism, new replenishments are expected to arrive when inventory levels reach the *SS* threshold, thereby maintaining uninterrupted supply continuity.

Shipment Size and Shelf-Life Constraints

In the EOQ model, shipment size is constrained by the maximum shelf life of each commodity. The maximum allowable inventory level is calculated as:

$I_{max} = d \times L_s$

where I_{max} denotes the maximum inventory level and L_s represents shelf life expressed in days.

Based on this constraint, the maximum shipment size is expressed as:

$Q_{max} = I_{max} - SS$

The operational shipment size ($Q*$) is set close to Q_{max} and adjusted to the vehicle capacity of 4,000 kg per vehicle to ensure practical applicability in field operations.

Distribution Cycle and Operational Rounding

The distribution cycle is determined as the ratio between the operational shipment size and daily demand:

$$T = \frac{Q^*}{d}$$

The resulting value of *T* is continuous (decimal). For operational purposes, the distribution cycle is rounded up to full-day units. This rounding is intended to simplify distribution scheduling and enhance operational discipline.

The rounding of the distribution cycle does not cause stockouts, as the inventory system is controlled by ROP and SS, which absorb timing discrepancies resulting from the rounding process.

Ordering Policies by Commodity

Based on the inventory models applied, the ordering policies for each commodity in this study can be summarized as follows:

a. **Rice**: EOQ with shelf-life constraints, 2-day SS, explicit ROP, and an upward-rounded distribution cycle.
b. **Eggs**: EOQ with shelf-life constraints, 2-day SS, explicit ROP, and a shorter distribution cycle than rice.
c. **Vegetables without cooling**: JIT, daily deliveries, and no physical SS formation.
d. **Vegetables with cold storage**: EOQ with shelf-life constraints, 1-day SS, explicit ROP, and a shorter distribution cycle.

These policies allow each commodity to be managed optimally according to its characteristics while maintaining overall consistency within the inventory system.

Preservation Technology Scenarios (Cold Storage)

This study compares two inventory management scenarios for vegetables: daily distribution based on JIT without cold storage and EOQ-based management with the implementation of cold storage. In the second scenario, the analysis considers not only the reduction in distribution frequency but also the operational costs of cold storage, including electricity consumption and facility maintenance. The comparison of these two scenarios is used to evaluate the trade-offs among distribution efficiency, operational flexibility, and increases in the total logistics system costs of the MBG Program.

RESULTS AND DISCUSSION

Annual Food Requirements of the MBG Program

Based on the assumed daily requirement of 42,467 MBG portions and 240 operational days per year, the main food requirements are calculated deterministically. The results indicate that the annual logistics volume of the MBG Program in Gunung Sindur Subdistrict is substantial and requires an efficient inventory system.

Table 4. Annual Food Requirements of the MBG Program

Commodity	Daily Requirement	Annual Requirement
Rice	6,370 kg/day	1,528,800 kg/year
Eggs	2,548 kg/day	611,520 kg/year
Vegetables	8,493 kg/day	2,038,320 kg/year

Table 4 shows that vegetables have the largest annual distribution volume, followed by rice and eggs. These volume differences have direct implications for distribution frequency and logistics costs, particularly given that each commodity is subject to different shelf-life constraints.

Rice Inventory Optimization (EOQ, ROP, and Ceiling Cycle)

Rice is analyzed using an EOQ model with a shelf-life limit of 14 days, a 2-day SS, and a 1-day lead time. The shipment size is set close to the maximum allowable level under the shelf-life constraint, after which the distribution cycle is rounded up for operational purposes.

Table 5. Results of Rice Inventory Optimization

Parameter	Value
Shelf life	14 days
SS	12,740 kg
ROP	19,110 kg
Operational shipment size	76,000 kg
Theoretical cycle	11.9 days
Operational cycle	12 days
Shipments per year	399
Annual distribution cost	IDR 399,000,000

The results indicate that rice can be managed with a relatively low distribution frequency. Rounding the distribution cycle up to 12 days does not pose a risk of stockouts, as ROP and SS are designed to cover demand during the lead time and to absorb timing differences resulting from the rounding process.

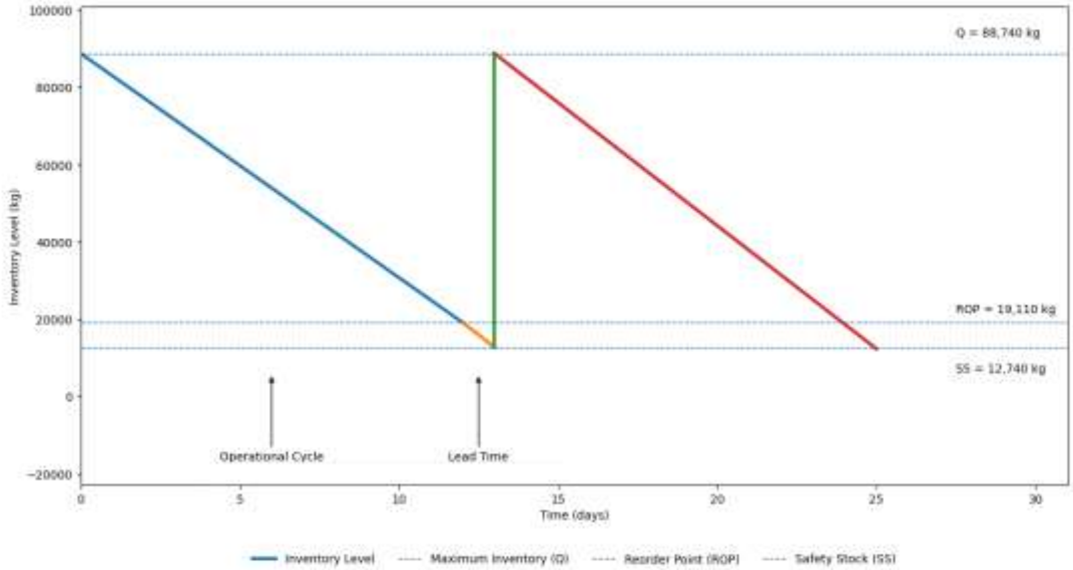

Figure 3. Rice Inventory Profile under the EOQ Model with SS and ROP

Reordering is triggered when inventory reaches the ROP level of 19,110 kg, which covers demand during the one-day lead time and a two-day SS. During the lead time, inventory is consumed until it reaches 12,740 kg, corresponding to the SS level. Upon delivery, an incoming shipment of 76,000 kg increases total warehouse inventory to 88,740 kg, representing the sum of the remaining stock and the replenished quantity. Inventory then decreases linearly following the daily consumption pattern.

The graph demonstrates that the operational maximum inventory level remains within the 14-day shelf-life constraint and that a theoretically continuous distribution cycle is implemented operationally through upward rounding to full-day units. The timing differences resulting from this rounding are absorbed by SS, thereby preventing stockouts. Consequently, the applied EOQ model effectively ensures the continuity of rice supply during the effective operational days of the MBG Program.

Egg Inventory Optimization (EOQ, ROP, and Ceiling Cycle)

Eggs have a shorter shelf life than rice, at 7 days. Consequently, shipment sizes and distribution cycles are smaller and more frequent.

Table 6. Results of Egg Inventory Optimization

Parameter	Value
Shelf life	7 days
SS	5,096 kg
ROP	7,644 kg
Operational shipment size	12,000 kg
Theoretical cycle	4.7 days
Operational cycle	5 days
Shipments per year	153
Annual distribution cost	IDR 153,000,000

Compared to rice, eggs require a higher delivery frequency. However, the application of EOQ with ROP and cycle rounding is still able to maintain supply continuity without increasing the risk of spoilage.

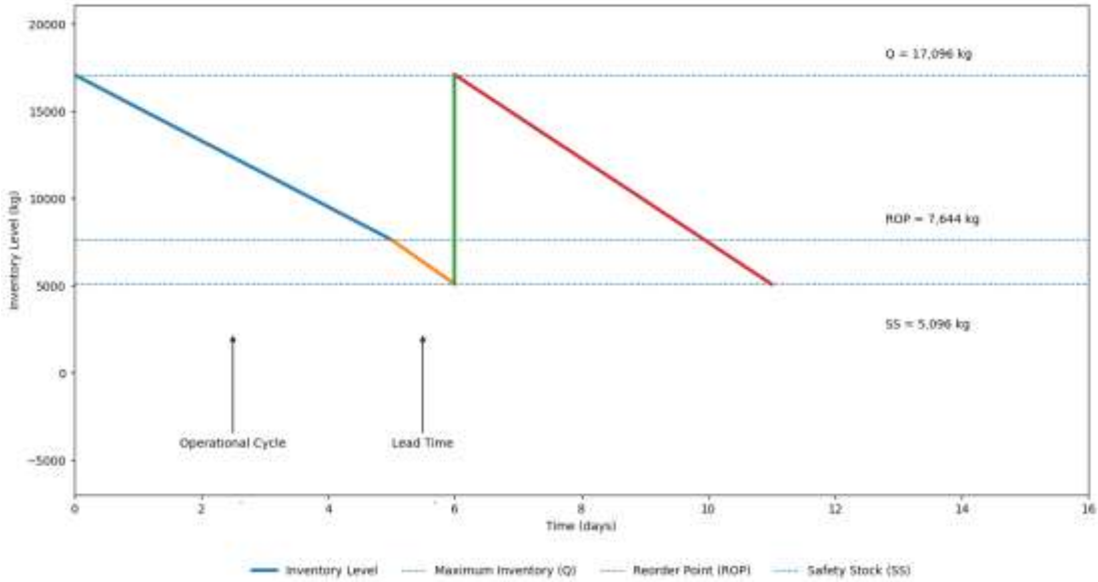

Figure 4. Egg Inventory Profile under the EOQ Model with SS and ROP

Figure 4 illustrates the egg inventory profile under the EOQ model controlled by SS and ROP over a one-week time horizon. The graph depicts only the effective operational days of the MBG Program and excludes non-operational days; therefore, consumption and distribution are assumed to occur continuously on service days. Egg demand is assumed to be constant at 2,548 kg per day. Reordering is triggered when inventory reaches the ROP level of 7,644 kg, which covers demand during the one-day lead time and a two-day SS. During the lead time, inventory is consumed until it reaches 5,096 kg, corresponding to the SS level. Upon delivery, an incoming shipment of 12,000 kg increases total warehouse inventory to 17,096 kg, representing the sum of the remaining stock and the replenished quantity. Inventory then decreases linearly following the daily consumption pattern. The figure also demonstrates that a theoretically continuous distribution cycle is implemented operationally through upward rounding to full-day units. The timing differences resulting from this rounding do not cause stockouts, as they are anticipated by the ROP and SS mechanisms. Accordingly, the applied EOQ model is able to ensure the continuity of egg supply during the effective service days of the MBG Program despite operational constraints in distribution scheduling.

Vegetable Distribution without Cold Storage Using JIT

Under conditions without the application of cooling technology, the shelf life of vegetables is assumed to be only 1 day, making the formation of cycle stock infeasible. Therefore, vegetable inventory management is conducted using a JIT approach with daily deliveries from suppliers to SPPG warehouses.

Table 7. Vegetable Distribution without Cold Storage

Parameter	**Value**
Inventory model	JIT
Shipment size	8,493 kg/day
Shipments per year	720
Annual distribution cost	IDR 720,000,000

Based on the results presented in Table 7, the JIT approach is able to maintain vegetable freshness through daily deliveries with a shipment size of 8,493 kg per day. However, this approach results in a very high distribution frequency, amounting to 720 shipments per year, thereby increasing distribution costs to IDR 720,000,000 per year. At the operational scale of the MBG Program, this condition imposes significant daily operational pressure and represents a major challenge in vegetable logistics management.

Vegetable Inventory Optimization with Cold Storage

The implementation of cold storage technology at the SPPG level is assumed to extend the shelf life of vegetables to 7 days, allowing inventory management to move beyond daily distribution. Under this assumption, vegetables can be managed using an EOQ model combined with SS and ROP to maintain supply continuity throughout the distribution period.

Table 8. Vegetable Inventory Optimization with Cold Storage

Parameter	**Value**
Shelf life	7 days
SS	8,493 kg
ROP	16,986 kg
Operational shipment size	24,000 kg
Theoretical cycle	2.83 days
Operational cycle	3 days
Shipments per year	480
Annual distribution cost	IDR 480,000,000

The results in Table 8 show that the implementation of cold storage significantly reduces the frequency of vegetable distribution compared to the JIT scenario, which requires daily deliveries. Nevertheless, this distribution efficiency must be evaluated comprehensively by accounting for the additional operational costs associated with cooling technology in the calculation of the total MBG logistics system cost.

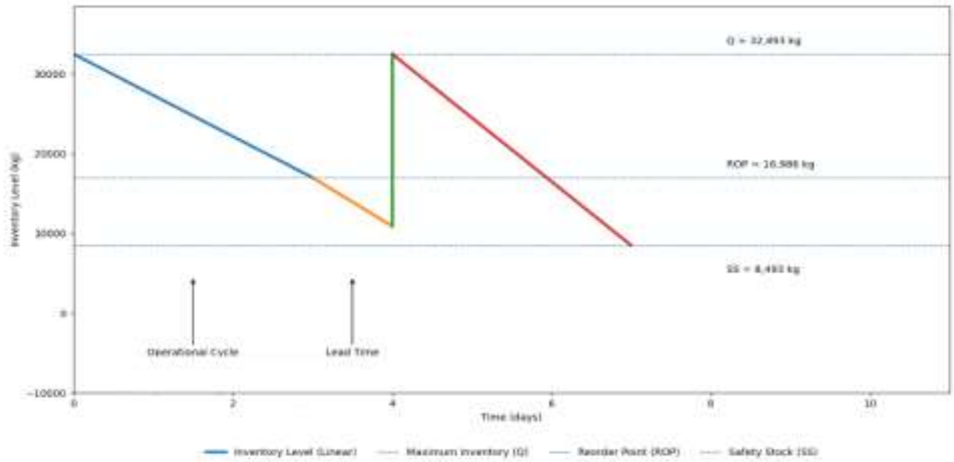

Figure 5. Vegetable Inventory Profile without Cold Storage under the EOQ Model with SS and ROP

Figure 5 illustrates the vegetable inventory profile under the EOQ model with the implementation of cold storage, controlled by SS and ROP over an effective 7-day time horizon. The graph represents only the operational service days of the MBG Program and excludes non-operational days; therefore, consumption and distribution are assumed to occur continuously on service days. Vegetable demand is assumed to be constant at 8,493 kg per day. Reordering is triggered when inventory reaches the ROP level of 16,986 kg, which covers demand during the one-day lead time and a one-day SS. During the lead time, inventory is consumed until it reaches 8,493 kg, corresponding to the SS level. Upon delivery, an incoming shipment of 24,000 kg increases total warehouse inventory to 32,493 kg, representing the combined remaining stock and replenished quantity. Inventory then decreases linearly following the daily consumption pattern. The figure demonstrates that the implementation of cold storage enables the formation of cycle stock for vegetables that previously required daily distribution. A theoretically continuous distribution cycle is implemented operationally through upward rounding to full-day units, and the timing differences resulting from this rounding are absorbed by SS, thereby preventing stockouts. Accordingly, the shelf-life-constrained EOQ model is able to maintain vegetable supply continuity more efficiently during the effective operational days of the MBG Program.

Performance Comparison of EOQ and JIT across Commodities

To evaluate the performance of the inventory approaches applied to rice, eggs, and vegetables, a comparison between the EOQ and Just-in-Time (JIT) models is conducted based on operational cycles and annual distribution costs.

Table 9. Comparison of MBG Inventory Models

Commodity	Inventory Model	Operational Cycle	Annual Distribution Cost (IDR/year)
Rice	EOQ + ROP	12 days	399,000,000
Eggs	EOQ + ROP	5 days	153,000,000
Vegetables	JIT	1 day	720,000,000
Vegetables	EOQ + Cold Storage	3 days	480,000,000

Based on Table 9, the performance of inventory models is strongly influenced by commodity characteristics. EOQ with ROP is effective for rice and eggs, which have adequate shelf lives, whereas vegetables without cooling must be managed using daily JIT distribution, resulting in high logistics costs. The application of EOQ with cold storage for vegetables reduces both distribution frequency and costs compared to JIT. Therefore, the selection of MBG inventory models should be tailored to the shelf-life and operational characteristics of each commodity.

Comparison of Cold Storage on Total System Costs

The integration of all commodities into a single logistics system reveals differences in total costs between scenarios without and with the implementation of cold storage. A comparison of the total costs of the MBG logistics system is presented in Table 10.

Table 10. Total Costs of the MBG Logistics System

Scenario	Distribution Cost (IDR/year)	Cold Storage Cost (IDR/year)	Total Cost (IDR/year)
Without cold storage	1,272,000,000	0	1,272,000,000
With cold storage	1,032,000,000	529,200,000	1,561,200,000

Based on Table 10, the implementation of cold storage reduces the annual distribution cost of the MBG Program from IDR 1.272 billion to IDR 1.032 billion. However, this reduction in distribution costs is offset by additional cold storage operational costs of IDR 529.2 million per year, resulting in an increase in total logistics system costs to IDR 1.561 billion per year. These findings indicate that, from a total system cost perspective, the application of cold storage for vegetables does not yet provide financial efficiency, despite its ability to reduce distribution frequency and enhance logistics operational flexibility.

SPPG Analysis

SPPG serves as the main operational unit in the implementation of the MBG Program, functioning as a center for food management, temporary storage, and food distribution to schools and beneficiary groups. Therefore, the number and operational level of SPPG units play a critical role in determining MBG service capacity and the logistics system burden at the subdistrict level. This subsection presents an analysis of the existing conditions of SPPG units in Gunung Sindur Subdistrict and an estimation of the required number of SPPG units to fully meet MBG beneficiary targets.

Current SPPG Conditions

Based on the implementation records of the MBG Program up to January 2026, Gunung Sindur Subdistrict has designated eight SPPG units. However, only six of these units are currently operational, while the remaining two have not yet commenced operations due to incomplete training stages and unmet environmental administrative requirements.

Table 11. Operational Status of SPPG Units in Gunung Sindur Subdistrict (January 2026)

No.	SPPG Name	Operational Status	Number of Staff	Beneficiary Groups	Actual Beneficiaries (persons)
1	SPPG Gunung Sindur 1	Operational	50	12	3,766
2	SPPG Gunung Sindur 2	Not operational	50	0	0
3	SPPG Gunung Sindur 3	Not operational	0	0	0
4	SPPG Pabuaran	Operational	50	7	3,937
5	SPPG Pengasinan	Operational	50	24	3,929
6	SPPG Rawakalong 1	Operational	52	18	3,674
7	SPPG Rawakalong 2	Operational	47	12	4,036
8	SPPG Rawakalong 3	Operational	50	7	2,233
Total					**21,575**

Source: https://mbg.bogorkab.go.id/

Table 11 indicates that the six currently operational SPPG units collectively serve 21,575 beneficiaries, with service capacities varying across units, ranging from 2,233 to 4,036 beneficiaries per SPPG. This variation reflects differences in the number of schools served, the spatial distribution of beneficiaries, and the operational readiness of each SPPG unit. Meanwhile, the two non-operational SPPG units listed in the same table are each planned to serve approximately 3,500 to 4,000 beneficiaries. Consequently, the actual service capacity of the MBG Program in Gunung Sindur Subdistrict has not yet reached the full beneficiary target.

Required Number of SPPG Units

The estimation of the required number of SPPG units is conducted by referring to the MBG beneficiary target of 42,467 individuals per day, which is based on the population aged 0–19 years as the primary target group. The calculation of SPPG requirements applies an average service capacity approach derived from currently operational SPPG units.

Based on existing conditions, the six operational SPPG units currently serve a total of 21,575 beneficiaries. Accordingly, the average service capacity per SPPG unit is approximately:

$$\frac{21.575}{6} \approx 3.596\,/\text{SPPG}$$

Using this average capacity, the number of SPPG units required to serve the entire MBG beneficiary target can be estimated as follows:

$$\frac{42.467}{3.596} \approx 11{,}8$$

The calculation results are rounded up, indicating that at least 12 SPPG units are required to fully serve all MBG beneficiaries in Gunung Sindur Subdistrict. Compared with the current condition of only eight SPPG units, there is a shortfall of approximately four SPPG units to achieve the ideal service capacity. The implications of these findings indicate that achieving the MBG Program targets depends not only on optimizing inventory and distribution models but also on increasing the number of SPPG units or enhancing the service capacity of existing SPPG units. An increase in the number of SPPG units would affect food distribution patterns, the number of active warehouses, and transportation frequency. Therefore, estimating SPPG requirements constitutes an important basis for medium-term MBG logistics system planning in Gunung Sindur Subdistrict.

CONCLUSION

Conclusions

This study analyzes inventory management in the MBG Program in Gunung Sindur Subdistrict using a multi-commodity inventory framework based on EOQ, JIT, and ROP under a deterministic quantitative approach, assuming a daily requirement of 42,467 portions over 240 operational days per year. The results show that the application of EOQ with ROP and SS is effective for commodities with medium to long shelf lives, namely rice and eggs, with annual distribution costs of IDR 399 million and IDR 153 million, respectively. For vegetables, the JIT approach results in the highest distribution cost, amounting to IDR 720 million per year due to daily delivery requirements. The implementation of cold storage enables the use of EOQ with a three-day distribution cycle and reduces vegetable distribution costs to IDR 480 million per year. However, the additional cold storage operational costs of IDR 529.2 million per year increase the total logistics system cost from IDR 1.272 billion to IDR 1.561 billion annually. From an institutional perspective, as of January 2026, only six out of eight SPPG units are operational, serving 21,575 beneficiaries, indicating that service capacity has not yet met potential demand. With an average service capacity of approximately 3,600 beneficiaries per SPPG unit, at least 12 SPPG units are required to fully serve the MBG beneficiary target. These findings emphasize that the success of the MBG Program depends not only on inventory model optimization but also on the adequacy of service capacity and the number of operational SPPG units.

Recommendations

The application of EOQ with ROP and SS is recommended for rice and egg commodities at the SPPG level, as it has proven effective in reducing distribution costs and maintaining supply continuity. For vegetables, a JIT approach remains necessary to preserve freshness; however, it should be supported by multiple distributors or suppliers with large production capacities to mitigate supply disruption risks. The implementation of cold storage should be considered selectively, particularly in areas with a high risk of distribution disturbances, although it has not yet proven efficient from a total system cost perspective. In addition, local governments should accelerate the operation of non-operational SPPG units and consider increasing the number or service capacity of SPPG units to ensure the sustainable fulfillment of MBG beneficiary needs. Future studies are recommended to incorporate demand uncertainty, lead time variability, and spatial distribution analysis to develop MBG inventory models that are more representative of real operational conditions.

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