A Distribution Planning Model for Subzided-Fertilizer Supply Chain Planning Considering Quota Allocation: A Case Study

Wahyudi Sutopo[1], Yuniaristanto[2], Wakit Pramono[3]
[1,2]Research Group in Logistics System and Business
[3]An adjunct researcher of Laboratory of Logistics System and Business
Department of Industrial Engineering, Sebelas Maret University
Jalan Ir. Sutami No. 36[a], Kentingan, Surakarta, 57126, INDONESIA
E-mail: [1] sutopo@uns.ac.id; [2] yuniaristanto@gmail.com; [3] logistiuns@gmail.com

Abstrak

Makalah ini membahas studi dunia nyata masalah perencanaan distribusi pupuk bersubsidi. Salah satu perusahaan pupuk nasional bahasa Indonesia memiliki kewajiban mendistribusikan pupuk bersubsidi-menjadi 15 kabupaten/kota di Propinsi Jawa Tengah. Perusahaan harus memenuhi permintaan pupuk bersubsidi-melalui saluran distribusi terkendal tingkat ketiga seperti lini I (pabrik), lini II (gudang provinsi), dan lini III (gudang kabupaten/kota). Lini I memasok lini II dan III dengan jumlah lebih besar dari pasokan dibandingkan dengan alokasi kuota yang sebenarnya berdasarkan keputusan gubernur. Pada kebijakan sebelumnya lini I mensuplai lini II dan III dengan stock pengaman untuk mengantisipasi permintaan selama 2 minggu dari distributor. Karena perubahan musim panen dan fluktuasi permintaan, lini II tidak dapat memenuhi permintaan dengan jumlah yang tepat, tempat, dan waktu. Kinerja pada tahun sebelumnya lebih dari 10% dari deviasi standar antara keputusan gubernur dan realisasinya. Fenomena ini menyebabkan meningkatnya biaya logistik seperti pemesanan, biaya transportasi, dan biaya simpan. Tujuan dari penelitian ini adalah untuk mengembangkan model untuk mendukung perusahaan untuk menentukan ukuran lot optimal dari lini II untuk berbaris I, dan *safety stock* pada Garis II dan III untuk meminimalkan biaya logistik. Sebuah model non-linear programming (MINLP) diusulkan untuk memecahkan masalah ini dengan mempertimbangkan metode peramalan baru untuk menghitung alokasi kuota. Ada lima kelompok kendala termasuk kapasitas gudang, kapasitas kendaraan, kuota, persediaan, dan variabel biner. Studi ini memberikan manfaat lebih dari 9% dari biaya logistik.

Kata kunci: perencanaan distribusi, biaya logistik, ukuran lot, *mixed integer non-linear programming*, *safety stock*, subsidi-pupuk.

Abstract

This paper investigates a real-world case study of a subsidized-fertilizer distribution planning. One of Indonesian national fertilizer company has an obligation distributing subsidized-fertilizer to 15 regency/municipality in Central Java Province. The company has to fulfill the demand of subsidized-fertilizer through a third-level controlled-distribution channels such as line I (factory), line II (province's warehouse), and line III (regency/municipality warehouse). Line I supplies line II and line III with higher amount of supply compare to the actual quota allocation based on the governor's decree. In the previous policy, line I supplied line II and line III with safety stocks to anticipate the demand for 2 weeks of distributors. Due to the changing of harvest season and demand fluctuation, line II cannot fulfill the demand with exact amount, place, and time. The performance at previous year is more than 10% of standard deviation between the governor's decree and the realization. This phenomenon causes the increasing of logistic costs such as ordering cost, transportation cost, and holding cost. The objective of this research is to develop a model for supporting company to decide the optimal lot size from line II to line I, and safety stock at Line II and III in order to minimize logistic costs. A mixed integer non-linear programming (MINLP) was proposed to solve this problem by considering a new forecasting method to calculate the quota allocation. There are five groups of constraints including warehouse capacity, vehicle capacity, quota, inventory, and binary variable. This study gives more than 9% benefit of logistic costs.

Keywords: *distribution planning, logistic costs, lot size, mixed integer non-linear programming, safety stock, subsidized-fertilizer.*

Introduction

The government of Indonesia provided heavy subsidies for fertilizer in order to ensure rational price for farmer/farmer groups and to support foodstuff production [1]. In 2006, according to the Trading Minister Policy No. 03/M-Dag/Per/2/2006, the Government made a regulation regarding procurement and distribution of subsidized fertilizer for agriculture sector. The government assigned respective producers to fulfill fertilizer's demand in each responsible region. The producer obligate to perform procurement and distribution of Subsidized Fertilizer in their responsible regions accord with necessary plan which stipulated by Minister of Agriculture. The Supply Chain of Subsidized-Fertilizer from producer to farmers is according to the Six Exactly Principle, namely exact kind, amount, price, place, time and quality. The company has to fulfi l the demand of subsidized-fertilizer through a third-level controlled-distribution channels such as line I (factory), line II (province's warehouse), and line III (regency/municipality warehouse) to retailers at line IV. The producer, distributor and retailer have terraced responsibilities as follows [2]: a) the producer obligate to perform procurement and distribution of Subsidized Fertilizer from Line I up to and including Line III in their responsible regions; b) the distributor obligate to perform procurement and distribution of Subsidized Fertilizer according to its utilization from Line III up to and including Line IV in their responsible regions; and c) The retailer obligates to perform procurement and distribution of Subsidized Fertilizer in Line IV.

PT. Pupuk Kaltim (PKT), one of fertilizer producer, has obligation to fulfill farmer's demand in 15 Regency/Municipality at Region II of Central Java Province. This obligation was organized by PKT Central Java Province Marketing Office (PKT-PJT). The company has to fulfill the demand of subsidized-fertilizer based on the Governor's Decree [4]. In the previous policy, line I supplied line II and line III with safety stocks to anticipate the demand for 2 weeks of distributors. Due to the changing of harvest season and demand fl PKT-PJT cannot fulfi the demand with exact amount, place, and time. The performance at previous year is more than 10% of standard deviation between the Governor's Decree and the realization. The Governor's Degree was allocated Subsidized-Fertilizer based on definitive plan groups organized by Agency of Agricultural in Regency/Municipality and in Province. This phenomenon causes the increasing of logistic costs such as ordering cost, transportation cost, and holding cost.

Based on above explanations, it is important to integrate key business processes including third-level controlled-distribution channels in order to minimize logistics costs. The integration of key business processes is required to achieve the suitable economic results and to leverage benefits [5,6]. Two strategic Supply Chain problems were addressed in this works especially for matching supply with demand [7]. The efficiency of a proposed supply chain was be assessed using the total logistics cost [8]. The objective of this research is to develop a model for supporting company to decide the optimal lot size from line II to line I, and safety stock at Line II and III in order to minimize logistic costs.

Problem Description

This work is not only for solving the real problem of Subsidized Fertilizer distribution problems in PKT-PJT but also trying to fill the research gaps in the area of lot sizing. We investigated the real condition to determine the relevant system then we studied several researches available regarding this issue performed before. The relevant system of the problem is illustrated in Fig. 1. It consists of four stages namely factory side (line I), PKT-PJT side (line II and III), demand side (distributor and retailer), and quota allocation decided by the Governor's Decree (the farmer's demand were calculated by Agency of Agricultural in Regency/Municipality and in Province). PKT-PJT has an obligation distributing subsidized-fertilizer to 15 Regency/Municipality in Central Java Province (Boyolali, Klaten, Sukoharjo, Wonogiri, Karanganyar, Sragen, Grobogan, Blora, Rembang, Kudus, Pati, Jepara, Demak Semarang/Salatiga and Surakarta).

Many contributors, for instant [3,9,10,11,12,13] have dealt with the quota allocation and the lot sizing problems. Rizk and Martel [14] and Robinson *et al.,* [15] were reviewing some of the work which has contributed to the current state-of-the-art of lot sizing models. Based on lot sizing problem, this work could be classifi as a Multi Level Lot-Sizing Problem (MLLP). Kilger and Wagner [10] proposed a demand planning framework that can be adapted as a method to determine quota allocation. Jeng, *et al.*, [12] described a multi-site two-stage production planning for the demand Management and capacity planning of TFT-LCD manufacturing. Agustina and Nur Bahagia [3] integrated model of 2 stages distribution

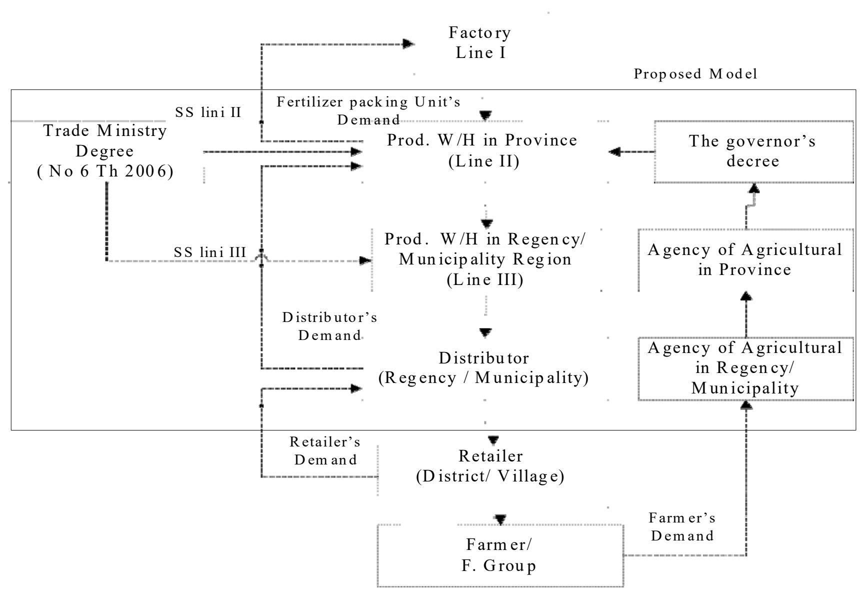

Figure 1. An overview of relevant system

regionalization system and subsidized cost in order to reach urea fertilizer's maximum price. Yuniaristanto, *et al.*, [13] developed 2 stages model of material planning and control to minimize the total inventory cost.

As in the papers cited above, none of the models is appropriate to solve the case study of 3 stages – 3 echelons distribution planning by minimizing total logistic costs. The quota allocation, safety stocks and lot sizing model from PKT-PJT to factory must be developed. The lot size and safety stock decision must be taken prior to the point in time when the quota allocation becomes known. In this work, a strategic level of supply chain distribution planning problem is addressed, that is the decision on quota allocation, safety stocks and economic lot sizing to ensure the distribution of subsidized-fertilizer in Central Java Province II region with exact amount, place, and time.

Model Formulation

There are three basic models in this research: quota allocation, safety stocks and economic lot sizing model. The quota allocation model contains demand planning structures, demand planning process and demand planning controlling. The quota model considers planting season, planting area, fertilizer doses and time per planting type. There is significant difference of planting season in each regency/municipality areas. This situation was forced to determine a specific fertilizer doses and time per planting type. For this reason, it is important to calculate safety stocks considering demand aggregation adopted from Chopra and Meindl [5]. A Mixed Integer Linear Programming (MILP) model is used to determine lot size including line II and III The in-hand stock of subsidized-fertilizer. Figure 2 shows a framework of three stages – three echelons distribution planning of this paper.

The model developed in this paper use the following notations:

Subscript symbols:

j Monthly planned time unit (j = 1,2,3,…, n),

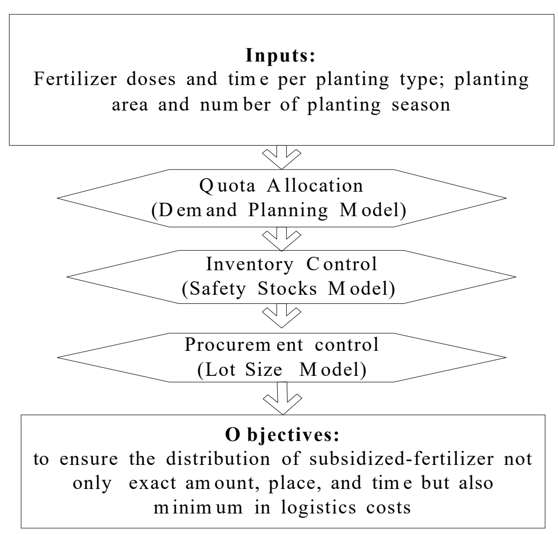

Figure 2. A framework of three stages – three echelons distribution planning

i W/H line III No. (i = 1,2,3,…, m),

l Number of plant type (l = 1, 2,3, …, 9).

Decision variables:

Q_{3ij} Lot size of subsidized-fertilizer that is allocated from line II to line III no. *i* in month *j* (*sacks*),

Q_{2j} lot size of subsidized-fertilizer that is ordered by line II to line I in month *j* (*sacks*),

b_j Indicate 1 if line II orders subsidized-fertilizer to line I and 0 otherwise,

I_{3ij} The in-hand stock at line III no. *i* in month *j* (*sacks*),

I_{2j} The in-hand stock at line II in month *j* (*sacks*),

SS_2 The safety stocks at line II (*sacks*).

Parameters:

T_i Transportation cost from line II to line III no. i (Rp./*sacks*),

O Ordering cost per unit of time (Rp),

H_{3j} Variable-holding cost at line III no. i per month (Rp./*sacks*),

Hf_{3j} Fixed-holding cost at line III no. i per planned time (Rp./*sacks*),

H_2 Variable-holding cost at line II per month (Rp./*sacks*),

Hf_2 Fixed-holding cost at line II per planned time (Rp./*sacks*),

K_{3i} Maximum-capacity of W/H line III no. i (*sacks*),

K_2 Maximum-capacity of W/H line II (*sacks*),

D_{3ij} Demand at line III no. i in month j (*sacks*),

D_{2j} Demand at line II in month j (*sacks*),

L_{li} Planting area for plant type no. l at regency/ municipality areas no. i per season (*hectare*),

LT_{li} Planting area for plant type no. l at regency/ municipality areas no. i per year (*hectare*),

J_l Number of planting season for plant type no. l per year.

The following formulation is used in the formulation of quota allocation:

$$D_{3ij} = \sum_{l=1}^{9} \frac{L_{lij} \times R_l}{p_l} \quad (1)$$

$$D_{3T} = \sum_{l=1}^{9}\sum_{i=1}^{m}\sum_{j=1}^{n} \frac{L_{lij} \times R_l}{p_l} \quad (2)$$

The plant types to be analyzed in the formulation of quota allocation which has: (1) wet rice; (2) unirrigated agricultural rice; (3) dry rice; (4) corn/maize; (5) cassava; (6) sweet potato., (7) peanuts; (8) soybean; and (9) green beans. This formulation will promote a quota allocation (S) which decided by the Governor's Decree.

The following formulation is used in the formulation of safety stocks:

$$L_{li} = \frac{LT_{li}}{J_l} \quad (3)$$

$$Var(D^c) = \sum_{i=1}^{15} \sigma_i^2 \quad (4)$$

$$\sigma(D^c) = \sqrt{\sum_{i=1}^{15} \sigma_i^2} \quad (5)$$

$$\sigma_L^{(c)} = \sqrt{Lx\,\sigma_D^C} \quad (6)$$

$$SS = F^{-1}(CLS)x\sigma_L^C = Norm\sin v(CSL)x\sigma_L^C \quad (7)$$

The following formulation is used in the formulation of lot size and stock in three echelons distribution planning with objective to minimize ordering cost, transportation cost, and inventory holding cost using a MILP.

The following objectives function is used in the formulation of minimal logistic costs:

$$Z = (O \times \sum_{j=1}^{n} b_j) + \sum_{i=1}^{n}\sum_{i=1}^{m}(T_i \times Q_{3ij}) + \sum_{i=1}^{n}\sum_{i=1}^{m}(I_{2j} \times H_2) + \sum_{i=1}^{n}\sum_{i=1}^{m}(I_{2ij} \times H_{3i}) +) \quad Hf_2 + HF_3 \quad (8)$$

Subject to:

$$Q_{3j} \leq K_{3i} \quad (9)$$

$$Q_{3j} \leq K_2 \quad (10)$$

$$Q_{3j}, Q_{2j} \geq 0 \quad (11)$$

$$Q_{3ij} \leq (K \times f) \quad (12)$$

$$\sum_{i=1}^{m}\sum_{j=1}^{n} Q3ij \leq S) \quad (13)$$

$$I_{3ij} = Q_{3j} + I_{3i(j-1)} \quad (14)$$

$$\sum_{i=1}^{m} Q_{3ij} \quad (15)$$

$$I_{2j} \geq SS_2 \quad (16)$$

$$I_{3ij} \geq 0 \quad (17)$$

$$bj \in \{0,1\}, \forall j \quad (18)$$

$$Q_{2j} \leq b_j \times M \quad (19)$$

The constraint set (9)–(11) ensures that each W/H is store the in-hand stock of subsidized-fertilizer under their maximum capacity. The constraint set (12) represents the capacity restriction of transportation modal. The constraint set (13) ensures that the total of subsidized-fertilizer allocated from line II to line III is under their quota. Equation (14–17) guarantees that each W/H in three echelons has optimal in-hand stocks. Constraint set (18–19) enforces the binary number of the decision variables and constraint.

Model Formulation

The optimal solution can be obtained by solving the pre-emptive of the A mixed integer non-linear programming (MILP) above. The methodology to solve the proposed problem is described as follow: (i) set the parameters of the a distribution planning model; (ii) formulate the objectives function in the MILP; (iii) formulate all the constraints of the solution model; and (iv) solve this model by using Microsoft Excel Solver 9.0.

In order to illustrate the capabilities of the proposed-model, a numerical example has been studied. Data input was obtained from Agency of Agricultural in Regency/Municipality and in Province and Central Statistic Board of Republic of Indonesia. We were calculated decision variables for 1 year planning horizon. The results above are summarized as below:

1) The total quota allocation in current system is 8,980,600 sacks while proposed system will suggest 10,028,670 sacks.
2) Based on safety stocks analyis, the proposed system will reduce to 78% in inventory (Table 1).
3) The Lot size allocation to Line III, Lot Size Ordered by Line II and Safety Stocks are presented in Table 2.
4) The frequency of delivery is presented in Table 3.
5) The total logistic costs in current system is Rp. Rp. 42,717.67 billion while proposed system will only expend Rp. 38, 821.16 billions. The proposed system will reduce costs up to 9%.
6) The Agency of Agricultural can propose a new system of quota allocation using this model.
7) The PKT-PJT can improve their procurement and distribution system using a proposed distribution planning model.

Table 1. Safety stocks analysis

No.	Echelon	Real System (Sacks)	Proposed System (sacks)	Saving (%)
1	SS Line II	3,593,856	1,045,896	70.9
2	SS Line III	3,652,577	515,572	85.8
3	Total	7,246,433	1,561,468	78.4

Table 2. Lot size allocation to Line III, Lot Size Ordered by Line II and Safety Stocks

Reg/ Mun.	Lot Size Allocation to Line III (Sacks)											
	Jan	Feb	Ma	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec.
Blora	31,118	123,046	107,038	50,386	68,272	123,848	61,928	62,462	62,462	62,774	108,152	49,272
Boyolali	24,008	71,966	64,790	35,936	42,044	71,966	37,560	34,424	34,424	65,306	68,560	5,304
Demak	55,288	125,000	89,338	119,112	125,000	75,132	24,174	75,132	75,132	89,220	90,806	1,600
Grobogan	98,400	125,000	112,134	125,000	125,000	108,088	86,046	86,046	108,774	125,000	125,000	4,608
Jepara	20,174	73,612	35,248	13,456	56,760	38,410	35,248	35,248	38,364	38,374	43,344	43,272
Kr.Anyar	1,874	61,956	30,778	6,174	42,564	65,494	31,178	48	30,778	64,458	37,080	6,174
Kendal	19,496	65,914	52,688	21,724	68,804	65,914	1,944	33,456	33,456	34,090	51,570	20,368
Klaten	26,454	79,022	39,432	12,220	51,160	79,890	39,590	182	39,590	41,184	51,238	48,876
Kudus	11,960	52,710	26,148	2,234	3,460	53,830	52,710	2,372	26,564	52,710	28,828	2,576
Pati	108,024	125,000	82,056	23,998	106,202	125,000	125,000	15,698	83,322	84,666	95,846	97,642
Rembang	20,012	33,392	55,580	58,378	34,762	33,392	31,292	31,292	7,038	34,112	87,064	55,048
Semarang	0	34,550	39,010	8,374	49,076	39,744	148	4,570	34,296	41,094	12,968	2,564
Sragen	120,646	125,000	10,382	43,642	125,000	125,000	3,238	68,746	68,746	72,268	77,248	10,382
Sukoharjo	0	68,052	41,320	13,564	39,492	35,694	35,694	58	35,694	75,526	41,322	41,320
Wonogiri	32,136	80,300	121,724	125,000	125,000	80,300	35,122	260	45,180	106,922	125,000	88,044
Lot Size	459,738	1,244,520	907,666	659,198	1,062,596	1,121,702	600,872	449,994	723,820	987,704	1,044,026	477,050
SS	87.158	87.158	87.158	87.158	87.158	87.158	87.158	87.158	87.158	87.158	87.158	87.158

Table 3. The frequency of Delivery

Reg/Mun.	Frequency of Delivery (Trucks)											
	Jan	Feb	Ma	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec.
Blora	62	246	214	101	137	248	124	125	125	126	216	99
Boyolali	48	144	130	72	84	144	75	69	69	131	137	11
Demak	111	250	179	238	250	150	48	150	150	178	182	3
Grobogan	197	250	224	250	250	216	172	172	218	250	250	9
Jepara	40	147	70	27	114	77	70	70	77	77	87	87
Kr.Anyar	4	124	62	12	85	131	62	0	62	129	74	12
Kendal	39	132	105	43	138	132	4	67	67	68	103	41
Klaten	53	158	79	24	102	160	79	0	79	82	102	98
Kudus	24	105	52	4	7	108	105	5	53	105	58	5
Pati	216	250	164	48	212	250	250	31	167	169	192	195
Rembang	40	67	111	117	70	67	63	63	14	68	174	110
Semarang	0	69	78	17	98	79	0	9	69	82	26	5
Sragen	241	250	21	87	250	250	6	137	137	145	154	21
Sukoharjo	0	136	83	27	79	71	71	0	71	151	83	83
Wonogiri	64	161	243	250	250	161	70	1	90	214	250	176

Summary and Extensions

A proposed distribution planning model is formulated considering 3 stages-3 echelons supply chain. The model can be used to make decision not only the lot size and safety stock including line II and III, but also the decision on quota allocation based on each region characteristics. A mixed integer linear programming (MILP) was proposed to solve this problem. There are five groups of constraints including warehouse capacity, vehicle capacity, quota, inventory, and binary variable. This study gives more than 9% benefit of logistic costs.

However, the actual work situation which can be changed all the time for all parameters. It is important to develop decision support system (DSS) for helping model application. This paper also has a certain limitation due to some assumptions to simplify the model. It is clear that the relaxation of these assumptions will provide additional challenges in future research.

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