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Genetic Algorithm for Solving the Integrated Production-Distribution-Direct Transportation Planning

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Abstract. *This paper proposes a model of integrated production, distribution and transportation planning for 4-echelon supply chain system that consists of a manufacturer using a continuous production process, a distribution center, distributors and retailers. By means of time-dependent demand at all retailers and direct transportation from one echelon to its successive echelons, the purpose of this paper is to determine production/replenishment and transportation policies at manufacturer, distribution center, distributors and retailers in order to minimize annually total system cost. Due to the proposed model is classified as a mixed integer non-linear programming so it is almost impossible to solve the model using the exact optimization methods and a lot of time is needed when the enumeration methods is applied to solve only a small scale problem. In this paper, we apply the genetic algorithm for solving the model. Using integer encoding for constructing the chromosome, the best solution is going to be searched. Compared with enumeration method, the difference of the result is only 0.0594% with the consumption time is only 0.5609% time that enumeration methods need.*

Keywords: *Production, Distribution, Direct Transportation, Genetic Algorithm*

1. INTRODUCTION

In supply chain management (SCM) concepts, all the entities (manufacturer, distribution center, distributor and retailer) should have coordination in satisfying their end customer. They coordinate their policy especially inventory and transportation. Generally, the location of manufacturer, distribution center, distributor and retailer are geographically separated. Therefore they have to decide inventory policies coordinately and also transportation policies.

Researches in multi-echelon inventory policy mainly have not integrated with the transportation policy, such as Santoso et al. (2007a, 2007b), Routroy and Kodali (2005), Weng (2004), Abdul-Jalbar et al. (2003), Nur Bahagia and Toruan, (2001), and Nur Bahagia (1999). Gaur and Fisher (2004), Nur Bahagia and Sofitra (2001), Chan and Simchi-Levi (1998), Chan et al. (1998), Viswanathan and Mathur (1997), and Santoso et al. (2008) have developed model of integrated inventory and transportation policies.

Similar with Santoso et al. (2008), this paper proposes model of integrated production, distribution and transportation planning for 4-echelon supply chain system. The 4-echelon supply chain system consists of a manufacturer using a continuous production process, a distribution center, distributors and retailers. This paper also considers direct transportation from one echelon to its successive echelons. This paper determines production/ replenishment and transportation policies at manufacturer, distribution center, distributors and retailers in order to minimize annually total system cost.

While Santoso et al. (2008) uses enumeration to solve

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the model that is classified as a mixed integer non-linear programming, this paper proposes genetic algorithm. Similar with Pasandideh and Niaki (2008), we use integer-value encoding for constructing the chromosome.

2. FRAMEWORK

This integrated production-distribution model is developed for 4-echelons supply chain systems that consists a manufacturer, a distribution center, a number of distributors and a number of retailers as is illustrated in the framework in Figure 1.

Using a continuous process causes the manufacturer produces the products continuously until the preventive maintenance schedule of the production facility or all demand during planning horizon had been produced. The length of planning horizon (T) is determined from available time before the schedule of preventive maintenance (w^t) and time consumption for maintaining the production facility (w^p).

$$T = w^t + w^p \qquad (1)$$

In other side, the customer demand that is faced by retailers fluctuates by time (time dependent demand). The manufacturer supplies all retailers through distribution center and distributor. The manufacturer, distribution center and distributor transfer the product to its successive echelon using direct shipping.

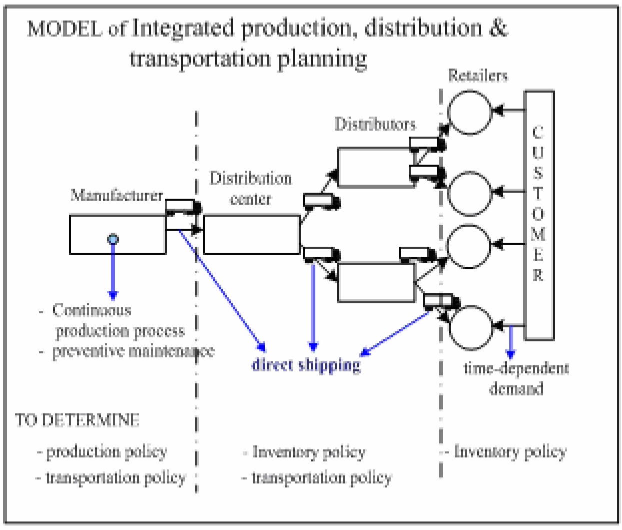

Figure 1. Framework

A coordinated production and replenishment policies between the manufacturer, the distribution center, the distributors and the retailers is needed for minimizing the total system cost.

Similar with Santoso *et al.* (2008), a coordinated policy, echelon inventory concept, and single cycle time policy are used as the approaches in developing the model. The coordinated policy approach leads the manufacturer, the distribution center, the distributors and the retailers to perform coordination for determining the production and the replenishment policies. All entities in the supply chain systems have to obey the production and the replenishment policies that have been decided. In the echelon inventory concepts, total inventory at an entity in one echelon is the sum of on-hand and in-transit inventories and all inventories at its downstream echelons (Clark and Scarf, 1960).

Using the single cycle time policy (Nur Bahagia, 1999 and Abdul-Jalbar *et al*., 2006) means that all entities start to produce or order product at the same time. As a result, the planning horizon (T) would be an integer multiplied by the replenishment cycle of distribution center (T^g), i.e., $T=N^gT^g$, where N^g is an integer. By the same token, the replenishment cycle of distribution center (T^g) is an integer multiplied by the replenishment cycle of distributor k (T^d_k) and the replenishment cycle of distributor k (T^d_k) is also an integer multiplied by the replenishment cycle of retailer j; $j \in k$ (T^r_{kj}). Generally, the single cycle time policy can be formulated as follow:

$$T = N^g T^g = N^g N_k^d T_k^d = N^g N_k^d N_{kj}^r T_{kj}^r \qquad (2)$$

where:

- N^g an integer of a multiplication of the replenishment cycle of the distribution center in a production cycle
- N^d_k an integer of a multiplication of the replenishment cycle of distributor k in a replenishment cycle of the distribution center
- N^r_{kj} an integer of a multiplication of the replenishment cycle of retailer j in a replenishment cycle of distributor k; $j \in k$

3. MODEL FORMULATION

The integrated production – distribution - direct transportation model is developed for determining production, inventory and transportation policy in order to minimize total system cost per planning horizon. The total system cost per planning horizon (C) consists of total cost per planning horizon at the manufacturer (C^o), distribution center (C^g), distributors (C^d) and retailers (C^r).

The assumptions used in developing the model are:

- The customer's demand at all retailers depend on time and are deterministic
- No stock-outs are permitted at all echelons
- Manufacturer can supply all of the distribution center's demand from its production and outsourcing
- At the beginning of planning horizon, there is sufficient inventory at manufacturer to fulfill the next

order of the distribution center.

- Outsourcing product at the manufacturer is allowed only if the production capacity is not enough to satisfy demand
- The production facility is never failure before the schedule of preventive maintenance
- Raw material are always available
- The entire replenishment lot size is added to inventory at the same time (for distribution center, all distributors and all retailers)
- Products at a distributor can not be transferred to other distributors; similarly at a retailer.
- Unit production cost; ordering cost at distribution centers, distributors and retailers; and transportation cost are constant

Customer demand at retailer that depends on time causes different maximum inventory in each order cycle at distribution center, distributor and retailer. Alike with Santoso et al. (2008), in this model, a polynomial function is used as an approximation for the time-dependent pattern of the customer demand. The implication of applying single cycle policy is distributor and their retailers make an order at the same time. Therefore, inventory position when distributor make an order to distribution center (ex. r^d_{k2}), should satisfy total orders that have to be delivered to its retailers (ex. q^r_{kj5}) as shown at Figure 2. In the same way, inventory position at the distribution center and manufacturer are calculated.

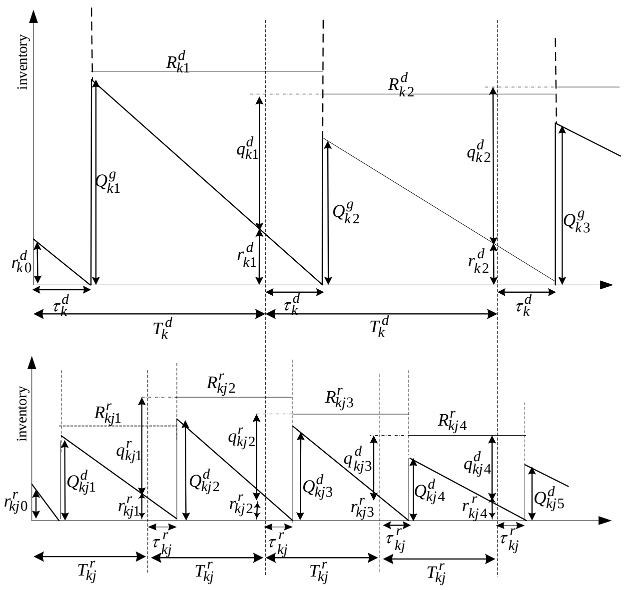

Figure 2. Inventory position at Distributor *k* and Retailer *j*

Total cost of retailer during planning horizon consists of ordering cost and holding cost at all of retailers. The ordering cost is calculated from order frequency during planning horizon and cost per order (A^r_{kj}). And the holding cost is calculated from average of inventory per planning horizon and carrying cost per unit per planning horizon (H^r_{kj}). According to the customer demand depend on time that is approached using polynomial function (z^r_{kj}), total cost of retailers can be formulated as follows:

$$C^r = \sum_k \sum_{j \in k} \left\{ \frac{A^r_{kj} T}{T^r_{kj}} + \frac{H^r_{kj}}{2N^g N^d_k N^r_{kj}} \sum_{s=1}^{N^g N^d_k N^r_{kj}} \int_{(s-1)T^r_{kj}}^{sT^r_{kj}} z^r_{kj}(t)\,dt \right\} \qquad (3)$$

A distributor delivers the product to several retailers that are geographically dispersed. Therefore, transportation cost is a cost component of distributor's total cost per planning horizon as well as ordering cost and holding cost. The ordering cost is obtained from order frequency during a planning horizon and cost per order (A^d_k). The holding cost that is found from average of inventory per planning horizon at distributor and carrying cost per unit per planning horizon (H^d_k). As result of using echelon inventory concept, total inventory at distributor k is the total inventory at distributor k itself and total inventory at all retailer *j* that are supplied by distributor *k*. The transportation cost consists of fixed and variable cost. Because distributor delivers product to its retailer directly, the number of vehicles that are used, are determined based on model of Gallego and Simchi Levi (1990). The variable transportation cost is influenced by number of vehicles, distance between distributor and its retailer (J_{kj}) and transport cost per unit distance (C^d). And the fixed cost is calculated of number of vehicles and fixed cost per vehicle (C^{dr}). While vehicle capacity is φ and total distributor's demand is the summation of total retailers' demand, the total distributor cost per planning horizon can be formulated as follows:

$$C^{dist} = \sum_k \left\{ \frac{A^d_k T}{T^d_k} + \frac{H^d_k}{2N^g N^d_k} \sum_{l=1}^{N^g N^d_k} \sum_{j \in k} \int_{(l-1)T^d_k}^{lT^d_k} z^r_{kj}(t)\,dt + \sum_{j \in k} \sum_s \left(C^d + C^{dr} 2J_{kj} \right) \left[\frac{1}{\varphi} \left(\int_{(s-1)T^r_{kj}}^{sT^r_{kj}+\tau^r_{kj}} z^r_{kj}(t)\,dt - \int_{(s-1)T^r_{kj}}^{(s-1)T^r_{kj}+\tau^r_{kj}} z^r_{kj}(t)\,dt \right) \right] \right\} \qquad (4)$$

Total cost of distribution center also consists of ordering cost, holding cost and transportation cost. In the same way, total distribution center cost can be formulated as follows:

$$C^{gdp} = \frac{A^g T}{T^g} + \frac{H^g}{2N^g} \sum_{p=1}^{N^g} \sum_k \sum_j \int_{(p-1)T^g}^{pT^g} z^r_{kj}(t)\,dt +$$

$$\sum_{k}\sum_{l=1}^{N^g N_k^d}\left(C^g + C^{gd}2J_k^{gd}\right)$$

$$\left[\frac{1}{\varphi^g}\sum_{j\in k}\left(\int_{(l-1)T_k^d}^{lT_k^d+\tau_k^d} z_{kj}^r(t)dt - \int_{\left(lN_{kj}^r-1\right)T_{kj}^r}^{lN_{kj}^r T_{kj}^r+\tau_{kj}^r} z_{kj}^r(t)dt + \int_{\left(lN_{kj}^r-1\right)T_{kj}^r}^{\left(lN_{kj}^r-1\right)T_{kj}^r+\tau_{kj}^r} z_{kj}^r(t)dt\right)\right] \quad (5)$$

where

- A^g cost per order at distribution center
- H^g carrying cost per unit per planning horizon at distribution center
- C^g fixed transportation cost per vehicle
- C^{gd} transportation cost per unit distance
- J^{gd}_k distance from distribution center to distributor k

At the manufacturer, production is run continuously until the time to maintain the production facility or all demands during the planning horizon are fulfilled. If the production is stopped before the products produced are enough to satisfy all demand, the manufacturer will outsource the lack of demand and production. Therefore, the total cost of manufacturer consists of set-up cost, outsourcing cost, holding cost and transportation cost.

The manufacturer cost is formulated using unit setup cost (A^o), maintenance cost (A^p), carrying cost per unit per planning horizon (H^o), production rate (ψ), unit outsourcing cost (P^{os}), fixed transportation cost per vehicle (C^o) and transportation cost per unit distance (C^{og}), vehicle capacity (φ^o) and distance from manufacturer and distribution center (J^{og}) as follows:

$$C^{pbrk} = \left(A^o + A^p\right) + H^o\left(\sum_k\sum_{j\in k}\left(\frac{1}{2}\int_0^T z_{kj}^r(t)\,dt - \frac{1}{2}\int_0^{t^p} z_{kj}^r(t)\,dt + \int_0^{T^g+\tau^g} z_{kj}^r(t)dt - \int_0^{T_k^d+\tau_k^d} z_{kj}^r(t)dt + \int_0^{T_{kj}^r+\tau_{kj}^r} z_{kj}^r(t)dt - \int_0^{\tau_{kj}^r} z_{kj}^r(t)dt\right) - \psi\tau^g\right) + P^{os}\left(\max\left(0, \sum_k\sum_{j\in k}\int_0^T z_{kj}^r(t)dt - \psi t^p\right) + \max\left(\sum_k\sum_{j\in k}\left(\int_0^{T^g+\tau^g} z_{kj}^r(t)dt - \sum_k\int_0^{T_k^d+\tau_k^d} z_{kj}^r(t)dt + \int_0^{T_{kj}^r+\tau_{kj}^r} z_{kj}^r(t)dt - \int_0^{\tau_{kj}^r} z_{kj}^r(t)dt\right) - \psi\tau^g, 0\right)\right) + \sum_{p=1}^{N^g}\left(C^o + C^{og}2J^{og}\right)$$

$$\left[\frac{1}{\varphi_o}\sum_k\sum_{j\in k}\left(\int_{(p-1)T^g}^{pT^g+\tau^g} z_{kj}^r(t)\,dt - \int_{\left(pN_k^d-1\right)T_k^d}^{pN_k^d T_k^d+\tau_k^d} z_{kj}^r(t)dt + \int_{(pN_k^d N_{kj}^r-1)T_{kj}^r}^{pN_k^d N_{kj}^r T_{kj}^r+\tau_{kj}^r} z_{kj}^r(t)dt - \int_{(pN_k^d N_{kj}^r-1)T_{kj}^r}^{(pN_k^d N_{kj}^r-1)T_{kj}^r+\tau_{kj}^r} z_{kj}^r(t)dt\right)\right] \quad (6)$$

The objection function is total system cost that consists of total manufacturer cost, distribution center cost, distributors cost and retailers cost. In this model, several constraints are used, i.e.:

$$T = N^g T^g = N^g N_k^d T_k^d = N^g N_k^d N_{kj}^r T_{kj}^r \quad (7)$$

$$\int_0^T z^o(t)\,dt = \int_0^T z^g(t)\,dt = \sum_k\int_0^T z_k^d(t)\,dt = \sum_k\sum_{j\in k}\int_0^T z_{kj}^r(t)\,dt \quad (8)$$

$$T^g \le T - t^p \quad (9)$$

$$t^p = \min\left[\left(\frac{1}{\psi}\sum_k\sum_{j\in k}\int_0^T z_{kj}^r(t)\,dt\right), w^t\right] \quad (10)$$

Ng, N^d_k, $N^r_{kj} \ge 1$ and integer value (11)

Constraint (7) pertains to use the single cycle time policy approach explained in the framework. Constraint (8) ensures that the total annual demand at manufacturer is the same as the total annual demand at distribution center, and also is the same as the total annual demand at all distributors and is the same as the total annual demand at all retailers. The next constraint (9) ensures that total order of the distribution center especially in the last replenishment cycle should be fulfilled. Constraint (10) guarantees there is no production when the production facility is maintained. And the last constraint (11) ensures decision variables have to be integer and always greater than zero.

4. GENETIC ALGORITHM

The model of integrated production, distribution and direct transportation planning is classified as a mixed integer non-linear programming. Therefore, it is almost impossible to solve the model using the exact optimization methods. It is needed a lot of time to solve only a small scale problem when the enumeration method is applied. In this paper, the genetic algorithm (GA) is applied to solve the model. Generally, framework of the genetic algorithm is shown in Figure 3.

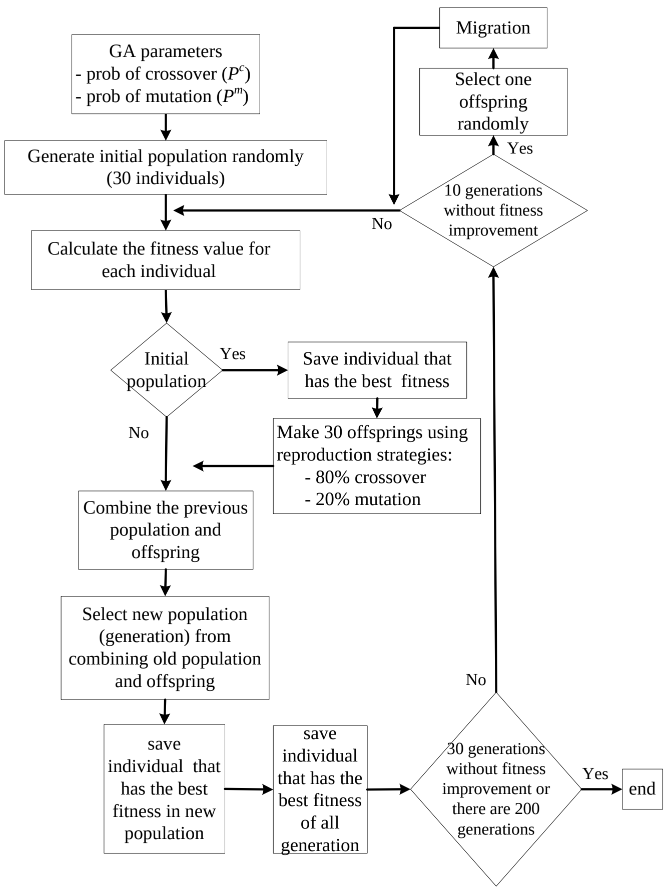

Figure 3. The framework of genetic algorithm

A chromosome (an individual) in population represents solution. Generally, binary encoding often is used in the genetic algorithm (Haupt dan Haupt, 2004). Because the decision variables of this model are integer so that integer encoding is applied to build the chromosome. The genetic algorithm in this model is developed based on genetic algorithm of Pasandideh and Niaki (2008).

The genetic algorithm starts from generating initial population. After the fitness values of each individual are calculated, the offsprings are generated using three reproduction strategies, i.e. crossover, mutation and migration. New population is selected from combining old population and offsprings that have the best fitness values.

4.1 GA parameter

GA parameters that are used for solving the proposed model are

- Population size for each generation = 30
- Probability of crossover (P^c) = 0.9
- Probability of mutation (P^m) = 0.2

4.2 Chromosome

The chromosome consists of genes that represent order frequency of an echelon in its upstream echelon (N^g; $N^d{}_k$; $N^r{}_{kj}$). Number of genes depends on number of order distribution center, distributors and retailers, as shown in Figure 4.

Figure 4. Genes in chromosome

4.3 Initial population

Exactly 30 individuals with the integer genes will be generated randomly. The first gene represents the frequency of distribution center's order cycle in one manufacturer's production cycle (N^g). The first gene has to satisfy constrain (9) in order to it is a feasible solution.

4.4 Calculating the fitness value

Fitness values that are the objective function of the proposed model are calculating while the chromosomes are generated.

4.5 Crossover

In crossover process, two chromosomes are selected randomly from the population. Generate an real value randomly for determining whether the crossover process is done or not (Pasandideh dan Naiki, 2008). If the real value less than P^c so the crossover is done. If the crossover is done, generate a set of binary values. Each binary value that is generated randomly is equal with 1 means the genes of two chromosomes will be crossover.

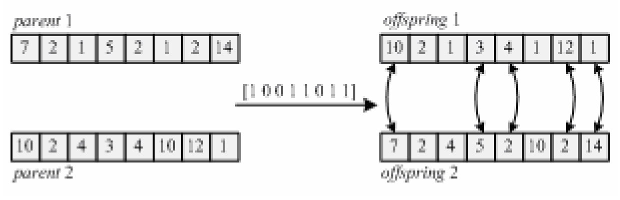

Figure 5. Crossover process with integer encoding

4.6 Mutation

One chromosome is selected randomly from population as a candidate that will mutate. A set of random values are generated to decide whether a gene will mutate or not. The gene will be mutated when the random value is less than P^m. A new gene is generated randomly. Mutation process is shown in Figure 6.

Figure 6. Mutation process with integer encoding

4.7 Migration

If the best fitness value throughout the generations does not change in last 10 generations, migration will be done. In migration process, an offspring will be selected randomly to be replaced with a completely new chromosome that all its genes are generated randomly.

4.8 New population (generation)

New generation is selected from combining old population and offspring that have the best fitness values. The offspring is performed from 80% crossover process and 20% mutation process.

4.9 Stopping rule

This genetic algorithm will be stopped when there are 200 generations or there are 30 generations without the best fitness improvement.

5. NUMERICAL EXAMPLE

The model will be applied using the following numerical example. The supply chain system consists of a manufacturer with a continuous production process, a distribution center, two distributors and five retailers as shown in Figure 7. Retailer R1 and R2 are supplied by distributor D1, while retailer R3, R4 and R5 are supplied by distributor D2.

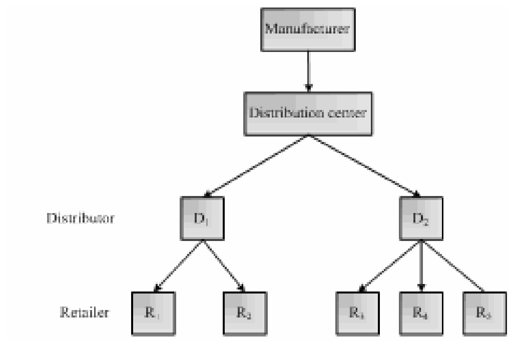

Figure 7: Supply chain system structure

The production facility that has production rate (ψ) 8,000 ton per year, is maintained periodically (w^t) each 0.8 years and requires 0.1 years to maintain it (w^p). The customer demand at each retailer that has time-dependent pattern is approximated using a polynomial function as shown in Table 1.

Table 1. Polynomial demand function at retailer

Retailer	Demand function
1	$f(t) = 82{,}590t^4 - 144{,}900t^3 + 79{,}830t^2 - 16{,}690t + 2{,}885$
2	$f(t) = 56{,}580t^4 - 91{,}310t^3 + 43{,}260t^2 - 6{,}067t + 2{,}071$
3	$f(t) = 92{,}310t^4 - 165{,}600t^3 + 93{,}850t^2 - 20{,}090t + 3{,}110$
4	$f(t) = 62{,}430t^4 - 115{,}300t^3 + 68{,}030t^2 - 16{,}170t + 3{,}236$
5	$f(t) = 8{,}927t^4 - 10{,}369t^3 + 2{,}562t^2 - 23.42t + 291.3$

Outsourcing cost is Rp. 1,200,000 per ton and the cost of each order/setup and carrying cost per ton per year are shown in Table 2. Vehicle capacity that is used at the manufacturer, distribution center and distributor, and distance between two locations can be seen at Table 3.

Table 2: Order/Setup cost and carrying cost

Echelon	Cost of each setup or order (rupiah)		Carrying cost per ton per year (rupiah)	
Manufacturer:	start-up cost (A^o)	6,500,000	H^o	149,200
	Maintenance cost (A^p)	6,000,000		
Distribution center	A^g	4,000,000	H^g	165,700
Distributor 1	$A^d{}_1$	4,500,000	$H^d{}_1$	183,600

Echelon	Cost of each setup or order (rupiah)		Carrying cost per ton per year (rupiah)	
Distributor 2	A^d_2	4,000,000	H^d_2	183,000
Retailer 1	A^r_{11}	100,000	H^r_{11}	195,000
Retailer 2	A^r_{12}	110,000	H^r_{12}	195,000
Retailer 3	A^r_{21}	125,000	H^r_{21}	195,500
Retailer 4	A^r_{22}	120,000	H^r_{22}	194,000
Retailer 5	A^r_{23}	120,000	H^r_{23}	195,500

Table 3. Distance, vehicle capacity and transportation cost

From - to	Distance (km)	Vehicle capacity (ton)	Transportation cost	
			fixed (Rp)	variable (Rp/km)
Manufacturer – dist. center	15	15	200,000	15,000
Distribution center - Distributor	Dist 1 : 30 Dist 2 : 25	20	150,000	13,000
Distributor – Retailer	Table 4 & 5	30	100,000	10,000

Table 4. Distance between two locations at distributor 1

		Distributor 1	Retailer	
			1	2
Distributor 1		0	10	15
Retailer	1	10	0	6
	2	15	6	0

Table 5. Distance between two locations at distributor 2

		Distributor 2	Retailer		
			3	4	5
Distributor 2		0	12	15	18
Retailer	3	12	0	8	10
	4	15	8	0	7
	5	18	10	7	0

In this numerical example, we do 5 replications for solving the model using the genetic algorithm scheme that is explained in above. According to formula of determining number of replications (Harrel et al., 2004), we only need 0.07933 replication. Therefore, it is proven that using 5 replications are sufficient for this case.

$$n = \left(\frac{z_{\alpha/2} s}{\left(\frac{re}{1+re} \right) \bar{x}} \right)^2 = \left(\frac{z_{0,05/2} (10,442,401,49)}{\left(\frac{0,05}{1+0,05} \right) 1,278,183,152.37} \right)^2 = 0.07933 \quad (12)$$

The result of 5 replications is shown in Table 6. Replication 3 has the smallest fitness and it is established after 51 generations. The graphic of the fitness for all generations is shown in Figure 8 and consumes 65 minutes.

Table 6. Fitness values of 5 replications

Replication	Fitness	Consumption time (minutes)	Generation
1	1,275,507,752.72	242	182
2	1,279,505,473.39	179	95
3	1,269,836,464.51	65	51
4	1,270,605,453.73	104	87
5	1,295,460,617.48	289	118
Mean	1,278,183,152.37	175,8	106,6
Min	1,269,836,464.51	65	51
Max	1,295,460,617.48	289	182
St.deviation	10,422,401.49	93.05751	48.54173

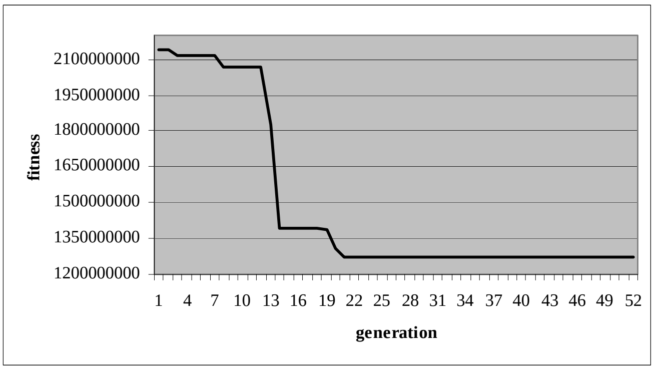

Figure 8. The fitness of all generations

The total system cost using enumeration is Rp. 1,262,343,126.81. It means the difference between using genetic algorithm and enumeration for solving the model is Rp 7,493,337.7 (0.594%). The consumption time of using enumeration methods for solving the proposed model is 31,344.71 minutes when the average consumption time of using genetic algorithm is 175.8 minutes. Hence, the genetic algorithm only needs 0.5609% of time that enumeration method needs. The result using genetic algorithm and enumeration is shown at Table 7.

Table 7. Comparison between result of genetic algorithm and result of enumeration

methods	Echelon	Length of cycle (year)		Order frequency in an order cycle of its upstream echelon	
Genetic algorithm	Distribution center	T^g	0.1250	N^g	8
	Distributor 1	T^d_1	0.1250	N^d_1	1
	Distributor 2	T^d_2	0.1250	N^d_2	1
	Retailer 1	T^r_{11}	0.1250	N^r_{11}	1
	Retailer 2	T^r_{12}	0.1250	N^r_{12}	1
	Retailer 3	T^r_{21}	0.0156	N^r_{21}	8
	Retailer 4	T^r_{22}	0.1250	N^r_{22}	1
	Retailer 5	T^r_{23}	0.1250	N^r_{23}	1
Enumeration	Distribution center	T^g	0.1250	N^g	8
	Distributor 1	T^d_1	0.1250	N^d_1	1
	Distributor 2	T^d_2	0.1250	N^d_2	1
	Retailer 1	T^r_{11}	0.1250	N^r_{11}	1
	Retailer 2	T^r_{12}	0.1250	N^r_{12}	1
	Retailer 3	T^r_{21}	0.0625	N^r_{21}	2
	Retailer 4	T^r_{22}	0.0625	N^r_{22}	2
	Retailer 5	T^r_{23}	0.1250	N^r_{23}	1

6. CONCLUSION

The model of integrated production-distribution-direct transportation planning is classified as a mixed integer non-linear programming. In this paper, we propose the genetic algorithm for solving the model.

Compared with enumeration method, the difference of the result is only Rp 7,493,337.7 (0.594%) with the consumption time is only 0.5609% of time that enumeration methods need. The total system cost using enumeration methods is Rp. 1,262,343,126.81 while the total system cost using genetic algorithm is Rp. 1,269,836,464.51.

In this paper, the model still considers deterministic time-dependent demand and direct shipping for transferring product at all echelon. In the future, we are going to consider probabilistic time-dependent demand and sharing shipping for transferring product at distributor.

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