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Integrated Transportation – Inventory Model for Outbound Logistics Optimization of Cement Product of PT. X

Hajariyah Agustina and Budi Santosa
Departemen of Management Technology, Institut Teknologi Sepuluh Nopember (ITS), Surabaya
e-mail: hajariyah.agustina@gmail.com

***Abstract*—In the cement industry, supply chain management has an important role in determining competitiveness from inbound logistics to outbound logistics. PT X is the largest cement company in Indonesia with market share about 53% in 2019. The Company's key strategy is supply chain optimization to achieve logistics and transportation cost efficiency and also prioritizing service level to meet customer needs. Outbound logistics optimization in PT X can be approached with the Integrated Transportation-Inventory (ITI) model. ITI is a model that integrates transportation and inventory decisions. In addition, ITI can also determine inventory levels, production quantities and backorder decisions. The application of ITI at PT X case study is categorized as multiple to multiple supply chain configurations, transshipment, multi-period, multi-product, allowing for back orders, and deterministic demand. The results of simulations of ITI models can be used as a basis sales planning and production. In this research, the ITI model solved with simplex solver method on Lingo 18, which has features to improve computational processes of a large scale cases. The development of the ITI model in optimizing outbound logistics at PT X provides efficiency and effectiveness of distribution strategy to meet customer demand. Simulation results show that optimization of outbound logistics using the ITI model is able to save costs by 1.86% (worth 117 billion) compared to existing conditions.**

***Keywords*—Supply Chain Management, Simplex, Multiple to Multiple, Transshipment, Multi Period, Multi Product.**

I. INTRODUCTION

SUPPLY chain management, according to "The Council of Supply Chain Management Professionals" (CSCMP), is a process of planning and managing all activities related to the sourcing and procurement process, production processes and logistics processes, which include coordination and collaboration activities with relevant stakeholders, such as suppliers, intermediaries / agents, third parties as service providers and consumers. In business processes, the implementation of supply chains is done to increase the service level to consumers, ensure quality of product, minimize operational costs and make the company more flexible to meet market changes. Supply chain optimization process has a very important role in supporting the achievement of company goals to be able to face market competition. This optimization process includes strategic efforts such as the determination of production facilities or operational ones such as fleet scheduling, production scheduling and stock level optimization.

In the cement industry, supply chain management has a very important role in determining "competitiveness" ranging from inbound logistics to outbound logistics. Outbound logistics is part of supply chain management that plans, implements, and controls the flow, storage of goods, services, and information from customer orders to product delivery. A characteristic of the cement industry is high in logistics costs. Cement raw material is the result of mining makes the decision to establish production facility close to the source of raw material, even though the final product, cement in bulk or bag, is a bulky product with a low economic value. This is what makes logistic outbound strategy in the cement industry plays a key role in determining cost efficiency so that it can increase its competitiveness.

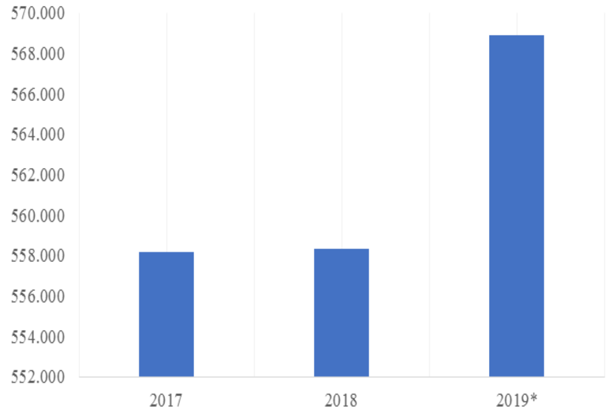

Figure 1. Cost of Goods Sold PT X From 2017 to 2019 (*Value until June 2019)

PT X is the largest cement company in Indonesia with market share reaching 53% in 2019. In the company's key strategy, Supply chain optimization has a major role to achieve the company's target growth. This supply chain optimization strategy seeks to get the minimum cost with the principle of achieving efficiency in logistics and transportation costs and still prioritizes the service level to meet customer needs [1]. This supply chain optimization strategy was formulated to be able to reduce distribution costs which increased by 0.003% in 2018 compared to 2017, and from 2019 to June the increase was quite high due to government regulations related to load restrictions and fuel price increases . As stated in Figure 1. PT X's cost of goods sold reached Rp. 568,691 / Ton which increased 1.8% from 2018. (Figure 1)

Outbound logistics optimization in PT X can be approached with the Integrated Inventory - Transportation model method. The Integrated Transportation-Inventory (ITI) Model is a model that integrates transportation and inventory decisions together [1]. In the matter of transportation (TP) there are several sources of products and several customers for one type of product or several products. Transportation optimization has the goal of minimizing total transportation costs by determining how much quantity from product sources to be sent to various customer destinations while taking into account product availability and other restrictions [2]. Whereas in inventory optimization there are sources of production in which carry out strategies to store products for the production process or delivery to various destinations. This is because if the supply of raw materials or products needed is not available in time, then the process of meeting the needs will be disrupted. On the other hand, inadequate stock of finished products leads to increased reputation, lost orders, etc. ITI considers the tradeoff of transportation costs and inventory costs in the decision making process with the aim of minimizing the overall total cost.

ITI application in completing logistics optimization has been widely developed including in logistics of oil products in China by Tang et al (2009) where the results of the study revealed that the ITI method as a method that is able to coordinate logistics activities and reduce total logistics costs, improve the efficiency of logistics systems, and can be a basis for increasing competitiveness through logistical program strategies[3].

The optimization of ITI PT X can be categorized as a NP-hard (non-polynomial hard) case that has the characteristics of the greater the size of the problem, the longer the computational time required. The ITI settlement method has a variety of scopes ranging from the exact method to the heuristic method. The exact method is an optimization method that uses the base of the simplex solver. In general, the exact method has a weakness if it is applied to cases that are very large and very complex because it will require very long computational time and the assumption that the problem must be linear. In this research, the ITI model developed will use the exact method through Lingo 18 software, which has features to accelerate the computing process in large-scale problems.

The development of the ITI model in optimizing the outbound logistics of PT X is expected to be able to provide efficiency and cost-effectiveness of distribution while continuing to meet customer needs through guaranteed product availability.

II. METHOD

The development of the ITI model considers the objective function which consists of minimizing the total cost of production costs, inventory costs, transportation costs, production costs and backorder costs. The objective function of minimizing total production costs will calculate the total value of production costs consisting of fixed costs and variable costs approached in units of Rp / ton multiplied by the number of products produced in each type, each period and each plant. The next objective function is minimizing inventory costs and backorder costs for each product in each period. This goal will provide a policy for companies to determine whether they are more effective in storing more products or to conduct a backorder policy by meeting demand in the next period. Costs to consider next are transportation costs, which consist of transportation costs from plant to customer, Plant to transshipment plant and plant to customer. This transportation cost optimization decision will produce an optimal product supply allocation route either directly from the Plant to the customer, or from the transshipment plant to the customer. The ITI model is described in a mathematical model that consists of several parts namely decision variables and parameters used in the model, the objective functions considered and the constraints in the model.

A. Parameter

The following are the parameters contained in the mathematical model of Integrated Transportation & Inventory for PT X:

k = Period ($k \in K$)

j = Type of product ($j \in J$)

o = Customer ($o \in O$)

i = Plant ($i \in I$)

n = Transshipment Plant ($n \in N$)

C_j^B = Backorder cost for product j (cost/unit)

C_j^P = Production cost for product j (cost/unit)

C_{ij}^{InP} = Inventory cost for product j plant i (cost/unit)

C_{nj}^{InT} = Inventory cost for product j transshipment plant n (cost/unit)

CT_{ijn}^{PT} = Distribution cost for shipment of product j from plant i to transshipment plant n (cost/unit)

CT_{ijo}^{PC} = Distribution cost for shipment of product j from plant i to customer o (cost/unit)

CT_{njo}^{TC} = Distribution cost for shipment of product j from transshipment plant n to customer o (cost/unit)

D_{ojk} = Demand for product j at period k for customer o (unit)

Cap^{ijk} = Production capacity for product j at period k at plant I (unit)

I_{ij}^{Inp} *Beginning* = Beginning Inventory at plant i for product j (unit)

I_{nj}^{Int} *Beginning* = Beginning Inventory at transshipment plant n for product j (unit)

B. Decision Variabel

The following are the decision variables considered in the mathematical model of the ITI problem:

P_{ijk} = Number of production of product j at plant i at period k (unit).

INP_{ijk} = Number of inventory of product j at plant i at period k (unit).

INT_{ijk} = Number of inventory of product j at transshipmentplant i at period k (unit).

B_{ojk} = Number of backorder of product j at customer o at period k (unit).

X_{ojik} = Number of delivered product j from plant i to customer o at period k (unit).

Y_{njik} = Number of delivered product j from plant i to transshipment plant n at period k (unit).

Z_{ojnk} = Number of delivered product j from transshipment plant n to customer o at period k (unit).

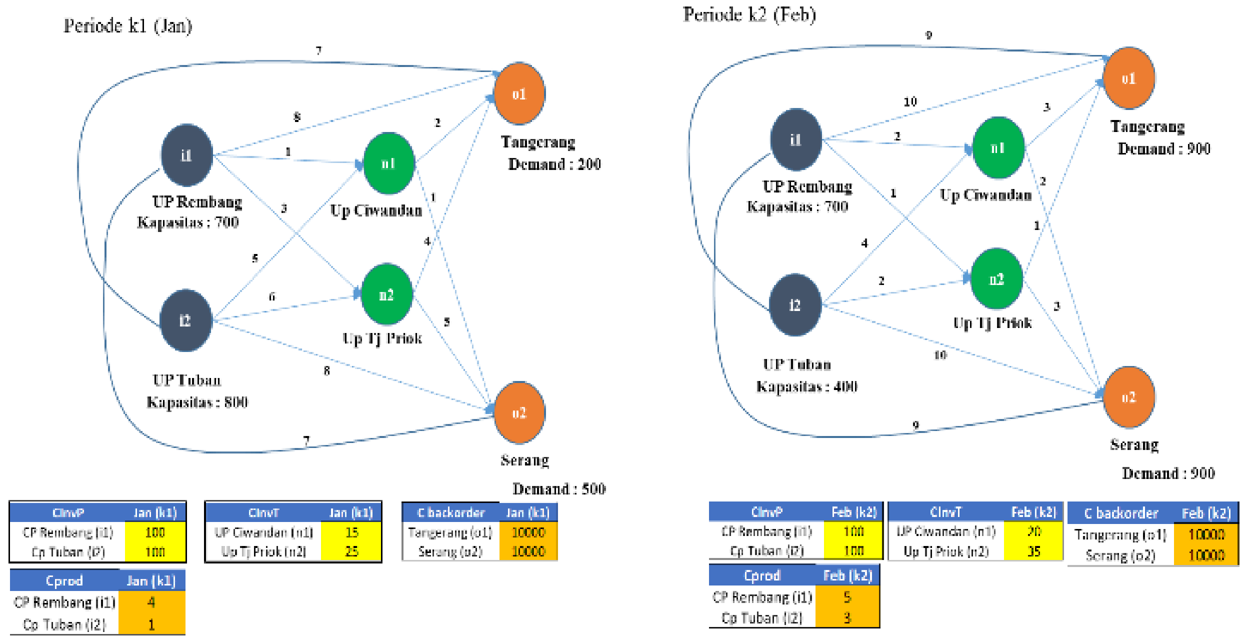

Figure 2. Data and Distribution Network of Data Test.

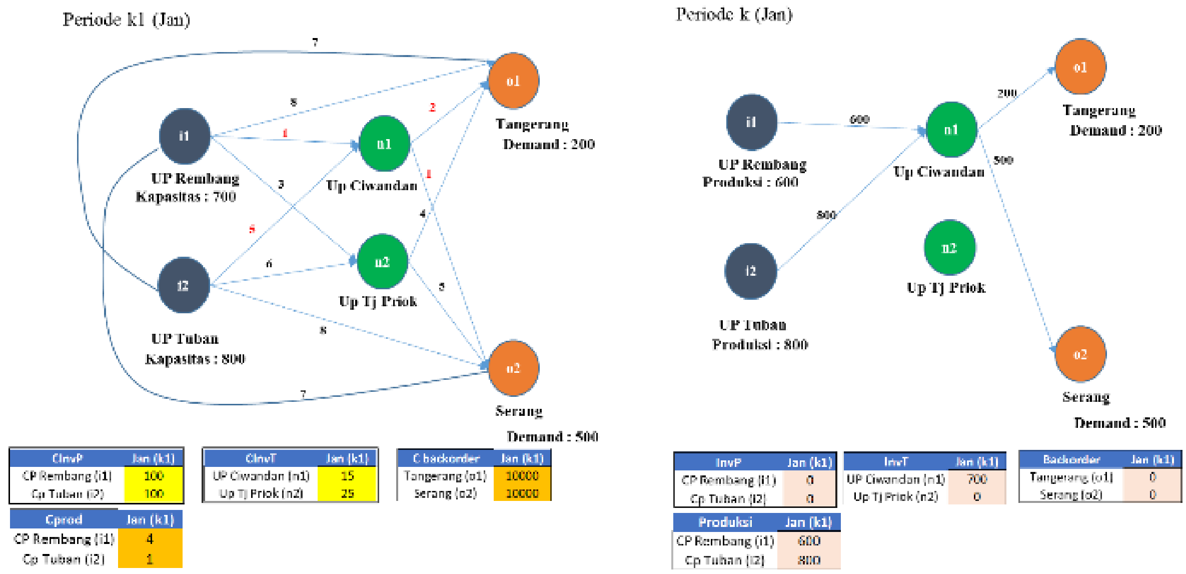

Figure 3. Decision on Allocation, Production, Inventory and Backorder on Test Data in 1st Period

C. Objective Function

The following are the objective functions considered in the ITI mathematical model. The objective function is to consider the total minimization of distribution costs, inventory costs, production costs, and backorder costs.

$$MinZ = \sum_{k=1}^{K}\sum_{j=1}^{J}\sum_{i=1}^{I}(C_j^P P_{ijk} + C_{ij}^{InP} INP_{ijk}) + \sum_{k=1}^{K}\sum_{j=1}^{J}\sum_{n=1}^{N} C_{nj}^{InT} INT_{ijk} + \sum_{k=1}^{K}\sum_{n=1}^{N}\sum_{j=1}^{J}\sum_{i=1}^{I} CT_{ijn}^{PT} Y_{njik} + \sum_{k=1}^{K}\sum_{n=1}^{N}\sum_{j=1}^{J}\sum_{O=1}^{O} CT_{njo}^{TC} Z_{ojnk} + \sum_{k=1}^{K}\sum_{i=1}^{I}\sum_{j=1}^{J}\sum_{O=1}^{O} CT_{ijo}^{TC} X_{ojik} + \sum_{k=1}^{K}\sum_{j=1}^{J}\sum_{o=1}^{O} C_j^B B_{ojk} \quad (1)$$

D. Constrains

The following are constraints used in this mathematical model:

$$P_{ijk} + I_{ij}^{Inp}\ Beginning = Y_{njk} + X_{ojik} + INP_{ijk}; k = 1, \forall i \forall j \quad (2)$$

$$P_{ijk} + INP_{ijk-1} = Y_{njk} + X_{ojik} + INP_{ijk}; k > 1, \forall i \forall j \quad (3)$$

$$Y_{njik} + I_{nj}^{Int}\ Beginning = Z_{ojnk} + INT_{njk}; k = 1, \forall n \forall j \quad (4)$$

$$Y_{njik} + INT_{njk-1} = Z_{ojnk} + INT_{njk}; k > 1, \forall n \forall j \quad (5)$$

$$P_{ijk} \le Cap^{ijk}; \forall i \forall j \forall k \quad (6)$$

$$D_{ojk} = Z_{ojnk} + X_{ojik} + B_{ojk}; k = 1, \forall o \forall j \quad (7)$$

$$D_{ojk} B_{ojk-1} = Z_{ojnk} + X_{ojik} + B_{ojk}; k > 1, \forall o \forall j \quad (8)$$

Constraints (2) and (3) are about inventory balance in each Plant. This constraint ensures that the amount produced is in accordance with its production needs by considering the amount of demand, backorder in that period, backorder in the

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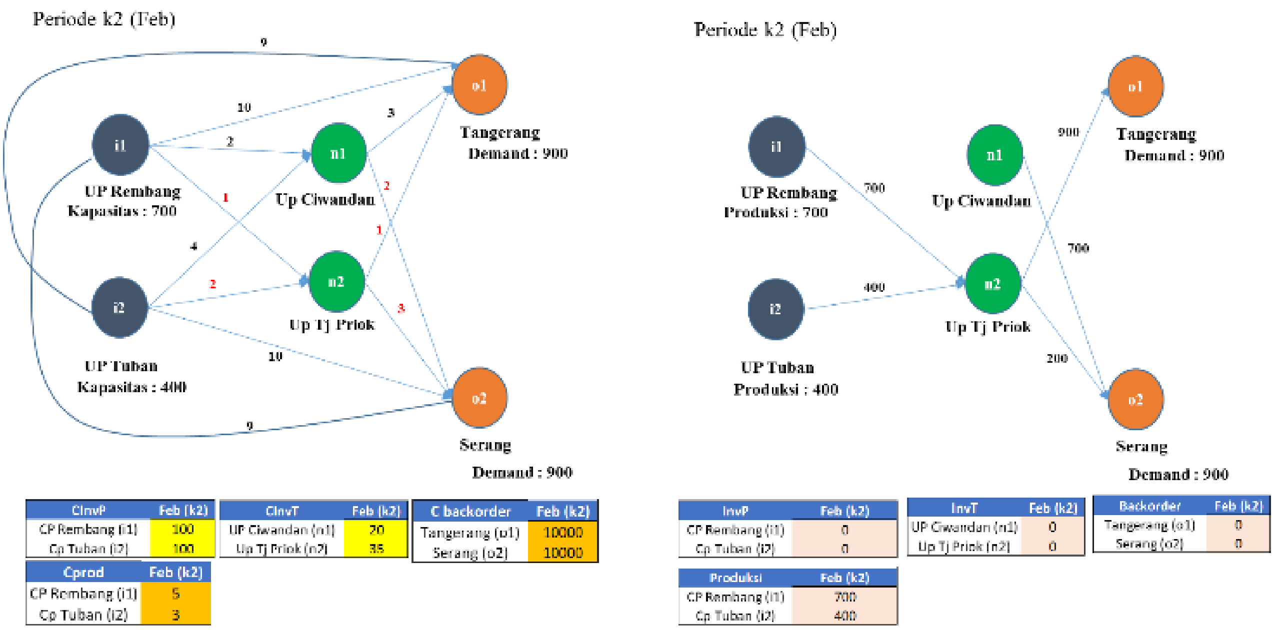

Figure 4. Decision on Allocation, Production, Inventory and Backorder on Test Data in 1st Period.

Table 1.
Product Types

Index	Tipe
J1	OPC CURAH
J2	OPC ZAK
J3	PCC CURAH
J4	PCC ZAK

Table 2.
Production Plant

Index	Plant
I1	CP CILACAP
I2	CP INDARUNG
I3	CP LHOKNGA
I4	CP NAROGONG
I5	CP REMBANG
I6	CP TONASA
I7	CP TUBAN

previous period, the amount of inventory in that period and inventory in the previous period. Constraints (4) and (5) are related to inventory balance in each Transsshipment plant. Constraint (6) is a limit on the production capacity for each product in each period of each plant. Whereas constrain (7) and (8) are about the fulfillment of demand for each product, at each customer in each period by considering the delivery process both from the plant and the transshipment plant as well as if there is backorder in the previous period.

E. Verification and Validation

Model verification is done by evaluating the structure of the model generated in the LINGO 18 software. Evaluation of the model is based on whether the generated model has a structure that is in accordance with the mathematical model. Then after verifying the model is validated. The validation of the mathematical model is done by comparing the computational logic of computational results with the logic of manual calculations. For verification and validation process its use small data test that consist of 2 Plant (i1,i2), 2 Transshipment Plant (n1,n2), 2 Customer (o1,o2) and 2 Periode (jan,feb). (Figure 2)

In the 1st period (Jan) total demand was 700 tons while

Table 3.
Planning Period

Index	Periode
K1	Jan
K2	Feb
K3	Mar
K4	Apr
K5	Mei
K6	Juni

Table 4.
Transshipment Plant

Index	Transhipment Plant	Index	Transhipment Plant
N1	GP CIGADING	N17	PP KENDARI
N2	GP DUMAI	N18	PP LAMPUNG
N3	GP GRESIK	N19	PP MAKASSAR
N4	PP ACEH LHOKSEUMAWE	N20	PP MAMUJU
N5	PP ACEH MALAHAYATI	N21	PP OBA
N6	PP AMBON	N22	PP PALU
N7	PP BALIKPAPAN	N23	PP PONTIANAK
N8	PP BANJARMASIN	N24	PP SAMARINDA
N9	PP BANYUWANGI	N25	PP SORONG
N10	PP BATAM	N26	PP TELUK BAYUR
N11	PP BELAWAN	N27	PP TJ PRIOK
N12	PP BENGKULU	N28	UP BATAM SBI
N13	PP BIRINGKASSI	N29	UP BELAWAN SBI
N14	PP BITUNG	N30	UP DUMAI SBI
N15	PP CEL BAWANG	N31	UP LAMPUNG SBI
N16	PP CIWANDAN	N32	UP PONTIANAK SBI

total production capacity was 1,400 tons, but in 2nd period the total demand was 1,800 tons while production capacity was only 1,100 tons. Therefore, to meet the demands of the next period, in 1st period the cement plant maximizes its production capacity to 1,400 tons. The cost of production between CP Tuban compared to CP Rembang is cheaper, so that more production decisions are made at CP Tuban with a capacity of 800 tons, the remaining needs then produced at CP Rembang by 600 tons. In an effort to balance the needs in 2nd period with limited production capacity, an inventory policy was carried out, which after comparing the cheapest

Table 5.
Summary of Production Planning, Inventory, Backorder and Distribution

Resume All	Jan	Feb	Mar	Apr	Mei	Juni
Demand	2.005.482	1.643.152	1.883.186	1.755.311	1.879.577	1.305.299
Beg Inv	205.000	98.310	77.833	46.088	34.023	15.920
Produksi	1.898.972	1.622.675	1.851.441	1.743.246	1.861.474	1.299.860
Distributed	2.005.482	1.643.152	1.883.186	1.755.311	1.879.577	1.305.230
End Inv	98.310	77.833	46.088	34.023	15.920	10.550
Backorder	0,00	-	-	-	-	70.000

Table 6.
Planning of Production, Inventory, Backorder and Distribution of Bulk OPC

OPC CURAH	Jan	Feb	Mar	Apr	Mei	Juni
Demand	614.519	497.497	571.371	535.975	582.017	402.302
Beg Inv	36.000	81.000	-	3.100	4.428	0
Produksi	578.600	497.416	574.471	537.303	577.589	402.302
Distributed	614.519	497.497	571.371	535.975	582.017	402.302
End Inv	81.000	-	3.100	4.428	0	0
Backorder	-	-	-	-	-	-

Table 7.
Planning of Production, Inventory, Backorder and Distribution of Bag OPC

OPC ZAK	Jan	Feb	Mar	Apr	Mei	Juni
Demand	7.163	6.225	6.777	6.461	6.463	4.295
Beg Inv	36.000	29.162	23.261	16.809	13.439	10.435
Produksi	325	325	325	3.090	3.459	2.410
Distributed	7.163	6.225	6.777	6.461	6.463	4.295
End Inv	29.612	23.261	16.809	13.439	10.435	8.550
Backorder	-	-	-	-	-	-

Table 8.
Planning of Production, Inventory, Backorder and Distribution of Bag PCC

PCC ZAK	JAN	FEB	MAR	APR	MEI	JUNI
DEMAND	1.279.928	1.050.588	1.204.163	1.120.807	1.196.542	832.046
BEG INV	*67.000*	*35.461*	*34.089*	*20.746*	*13.104*	*4.084*
PRODUKSI	1.248.388	1.049.215	1.190.820	1.113.164	1.187.522	828.892
DISTRIBUTED	*1.279.928*	*1.050.588*	*1.204.163*	*1.120.807*	*1.196.542*	*831.976*
END INV	35.461	34.089	20.746	13.104	4.084	1.000
BACKORDER	-	-	-	-	-	70

Table 9.
Planning of Production, Inventory, Backorder and Distribution of Bulk PCC

PCC CURAH	JAN	FEB	MAR	APR	MEI	JUNI
DEMAND	103.872	88.842	100.875	92.069	94.555	66.657
BEG INV	*66.000*	*33.607*	*20.483*	*5.432*	*3.051*	*1.400*
PRODUKSI	71.479	75.718	85.824	89.688	92.904	66.257
DISTRIBUTED	*103.872*	*88.842*	*100.875*	*92.069*	*94.555*	*66.657*
END INV	33.607	20.483	5.432	3.051	1.400	1.000
BACKORDER	-	-	-	-	-	-

inventory costs was at UP Ciwandan, which was Rp 15, so that aside from being allocated to meet demand, there would be an inventory of 700 Ton UP at Ciwandan. Based on test data, backorder policies are not used because the costs are higher than the total production costs, inventory costs and distribution costs to these customers. The allocation policy considers the comparison of the least expensive distribution costs to each customer. The lowest cost of distribution to Tangerang si using route UP Ciwandan - Tangerang, and the lowest distribution cost to Serang is using route UP Ciwandan – Serang. Details of production, inventory, allocation and backorder decisions for period 1 are shown in Figure 3.

Figure 4 shows the decisions on allocation, production, inventory and backorder in 2nd periode. Where in this 2nd period there was inventory in the previous period that was stored in UP Ciwandan to be able to meet the demand for soaring demand in 2nd period . In addition, the allocation policy also experienced changes to due to changes in distribution costs in 2nd period. These cost changes are shown to determine the sensitivity of the model if there are changes in costs in the next period. By still considering the comparison of the cheapest distribution costs to each customer, the distribution cost to Tangerang is the cheapest if taking the UP Tj Priok - Tangerang route, and the lowest distribution cost to Serang is the UP Ciwandan - Serang and UP Tj Priok - Serang. The total cost generated was 28,200.

Table 10.
Cost Comparison

Periode	Volume	Rp/Ton
2019 Real	10.401.690	568.691
2019 Simulasi	10.471.938	557.483
%		1,86%

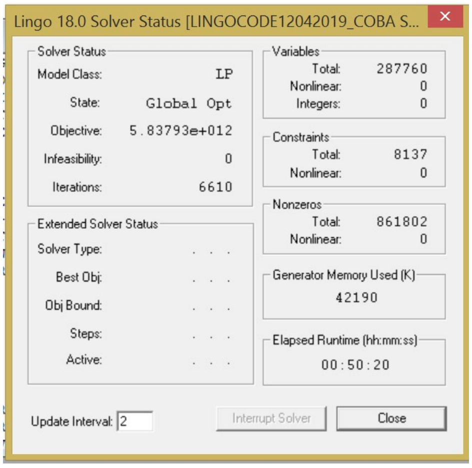

Figure 5. Lingo Status for Experiments on Test Data.

III. DATA

Data is for the 2019 planning period, including data demand, number of plants, product types, number of plant transshipment, and production capacity. The type of product considered is the product with the greatest demand in 2019, while the production plant is assumed to have Plant Tuban SMI and Plant ex Holcim Tuban to 1 so that there are only 7 plants. Meanwhile there are 32 transshipment plants considered throughout Indonesia. For the number of customers, there are 293 customers spread across 31 provinces from Aceh to West Papua.

IV. RESULTS AND DISCUSSION

Experiments were carried out using LINGO 18 software. LINGO 18 was used to conduct model experiments with the exact method using the simplex method. The computer specifications used are Intel® Core ™ i7-5500U CPU @ 2.40 G.Hz, 8 GB RAM. Based on the results of experiments conducted using LINGO with reference to case studies with parameters of 4 products, 6 periods, 7 plants, 32 transshipment plants, and 293 customers, the results are as a running model as follows on Figure 5.

From the status solver in Lingo 18 in Figure 2, it was found that the model is a Linear Programming with a total of 287,760 variables, 8137 constraints and takes 30 minutes 17 seconds to reach the global optima. From the simulation results, the objective function value for the total cost is Rp. 5,837,925,000,000.

The simulation results that have been carried out using LINGO 18 and MS Excel, the production planning, inventory, backorder and distribution allocation are obtained on Table 5-9.

Based on the results of the simulation, the objective function value is Rp. 5,837,925,000,000 for sales volume 10,471,938 tons so the average cost generated is Rp. 557,483 / ton. These results are then compared with the realized costs up to June 2019, which is Rp. 568,691 / ton. (Figure 10)

Based on these cost comparisons, it can be concluded that the outbound logistics optimization of PT X by using the ITI model is able to save costs by 1.86% (worth Rp 117.367.751.698) compared to existing conditions compared to the existing conditions

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