A Model for Procurement and Inventory Planning for Export-Oriented Furniture Industry in Indonesia: A Case Study

Wahyudi Sutopo, Anita O.T. Devi, Muhammad Hisjam, and Yuniaristanto

***Abstract*— Wooden furniture industry often face problems related to raw material, so the determination of procurement and inventory is important to minimize inventory cost. In this paper, we consider the accumulation of raw material purchasing cost, inventory cost, and direct labor cost. In the first step of modeling, system characteristics are described and we define some variables influencing relevant system. The model uses procurement system in accordance with raw material and semi-finished goods inventory system. The model was solved by putting parameter values from case study company's data. Linear programming (LP) approach was used to determine three decision variables namely quantity of log purchasing, inventory of log, and inventory of shelf. The results showed that total cost of procurement and the total of wood working can be reduced for a year planning horizon.**

***Index Terms*— inventory, linear programming, optimization, procurement.**

I. Introduction

EXPORT oriented furniture industry plays important role in Indonesia, because it contributes for increasing of GDP, providing job opportunities, and increasing prosperity [1]-[3]. Furniture industry that we study is furniture industry with main material is wood, especially teak wood. Most of teak wood furniture producers spread over in Java Island especially in Solo Raya [4]-[7]. Many problems faced by wooden furniture industry in Solo Raya, *i.e.* teak log scarcity, inefficiency in business operations and marketing problems [5]-[7]. Those problems make this industry less competitive than other countries [8], [9]. The proofs of this condition are the decrease of the number of the industry and less of export value in recent years [10].

In the furniture we study, the scarcity of main raw material makes the availabilty cannot be assure in all month of the year and the price becomes higher from year to year. Whereas the cost of material is the biggest part of the total cost. The main supplier of main raw material is Perum Perhutani, a state owned company that manages forest in Java and Madura Island. Due to the responsibility of Perum Perhutani to manage sustainable forest and other limitations, Perum Perhutani can only provide teak log in limited quantity and in certain months [4], [5]. It is necessary for the company to manage its inventory to assure the availability of raw material for production. Therefore, the decrease in the total cost of procurement and manufacturing of raw materials can be a solution in lowering the company's total expenditure for one year. The total cost of procurement and the total cost of manufacturing consist of the purchase cost of raw materials in the form of logs, log inventory cost of raw materials and semi-finished boards as a material and direct labor costs.

In the last few years, there were many models developed related to inventory planning [11]-[14] and procurement planning [15]. Unfortunelly, none of the models is appropriate to solve the case study by minimizing the total cost of procurement and manufacturing. Further, this research is trying to fill the research gaps. Meanwhile, it also comes up with the real problem of raw material in a company of export-oriented furniture industry in Indonesia.

This paper is organized as follows. In Section 1, we propose the background of our research and describe the problems in real system. In Section 2, we construct the modelling framework. In Section 3, we provide the mathematical model formulation for solving the problem. In Section 4, we design the solution method and analysis. In Section 5, we deliver the conclusion and future research.

II. Modeling Framework

In general, business process in in a company of export-oriented furniture industry can be depicted as in Fig. 1. The supplier for the furniture is Perum Perhutani that supplies in two class of log AII and AIII [4]. The inventory consist of log that purchased from Perum Perhutani and board that previously worked from partly of log. The wood working for board is intended to minimize span time of product ordered. In production, there are many activities, such as sawing log to board, or to RST (Rough Sawn Timber), or to component; drying; drilling; turning; assembling; and finishing. Finished goods are packed to be loaded to container.

W. Sutopo, M. Hisjam, and Yuniaristanto are with the Laboratory of Logistics and Business System, Department of Industrial Engineering, Sebelas Maret University, Surakarta, 57126, INDONESIA. (Corresponding authors: phone/fax.+62-271-632110; e-mail: sutopo@uns.ac.id; mhisjam@uns.ac.id; yuniaristanto@gmail.com).

A.O.T. Devi is an alumnae of Department of Industrial Engineering. Sebelas Maret University, Surakarta, 57126, INDONESIA. (e-mail: umm1_ana@yahoo.com).

ISBN: 978-988-19251-9-0
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

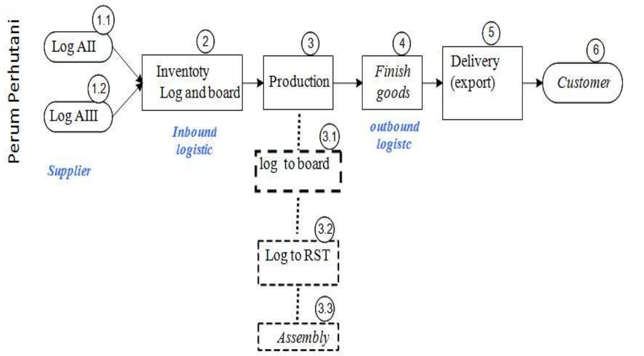

Fig. 1 Business process in the furniture industry.

The problem in this study is how to determine the number of purchases and supplies of teak log (Log AII and Log AIII), so the total costs of procurement and manufacturing of raw materials per year can be reduced and demand remains fulfilled. The objective of this model is not only to minimize the procurement's cost and manufacturing's cost, but also to ensure the availabilty or teak log and board in a furniture company for a year planning horizon.

III. Mathematical Model Formulation

This paper deals with a problem of procurement and inventory planning. The notations for this model are given in Table I and the decision variables are given in Table II.

TABLE I
DEFINITION OF NOTATION SETS

Notation	Definition of notations
$i \in I$	index product (1 = GF, 2 = INDOOR)
$j \in J$	index for class of log (1 = AII class, 2 = AIII class)
$t \in T$	index for monthly period (t = 1, … , 12)
p_{jt}	log price for j class t period (Rp/m^3)
d_{it}	demand of product *i* in period *t* (m^3)
q_{ijt}	volume of product *i* produced from log of class *j* in period *t* (m^3)
$ch_{i,t}^{IS}$	inventory cost of log for product *i* in period *t* (Rp/m^3 year)
$ch_{i,t}^{IS}$	inventory cost of board for product *i* in period *t* (Rp/m^3 year)
cr^{S}	regular cost for making board (Rp/m^3)
co^{S}	overtime cost for making board (Rp/m^3)
q_{it}^{S}	production of board for product *i* in period *t* (m^3)
$qr_{i,t}^{S}$	production of board time for product *i* in period *t* in regular (m^3)
$qo_{i,t}^{S}$	production of board for product *i* in period *t* in overtime (m^3)
$k_{i,j}$	conversion value of product *i* to log of class *j*
Inv^{max}	capacity of inventory raw material maximum (m^3)
r^{max}	capacity of board production maximum (m^3/month)
o^{max}	capacity of overtime maximum (m^3/month)
α	conversion value of board to *log*
β_i	conversion value of *i product* to board
TCM	procurement cost
TCI	inventory cost
TCP	direct labor cost for making board

TABLE II. THE DECISION VARIABLE OF PROPOSED MODEL

Notation	Definition of decision variables
Q_{ijt}	procurement of log class *j* for product *i* in period *t*
Q_{it}^{IL}	inventory of log for product *i* in period *t*
Q_{it}^{IS}	inventory of board for product *i* in period *t*

The procurement and inventory planning model then can be formulated as Linear Programming (LP). In (1) with time horizon of 1 year, we minimize total cost that consist of procurement cost, inventory cost, and direct labor cost.

$$Z_{\min} = \sum_{t=1}^{12}\sum_{j=1}^{2}\sum_{i=1}^{2} p_{jt}\, Q_{ijt} + \sum_{t=1}^{12}\sum_{i=1}^{2} ch_{it}^{IL}\, Q_{it}^{IL} + \sum_{t=1}^{12}\sum_{i=1}^{2} ch_{it}^{IS}\, Q_{it}^{IS} + \sum_{t=1}^{12}\sum_{i=1}^{2} cr^{S}\, qr_{it}^{S} + \sum_{t=1}^{12}\sum_{i=1}^{2} co^{S}\, qo_{it}^{S} \qquad (1)$$

subject to

$$\sum_{t=1}^{12}\sum_{j=1}^{2} q_{ijt} \geq \sum_{t=1}^{12} d_{it} \quad (\forall i) \qquad (2)$$

$$Q_{ijt} - k_{i,j}\, q_{ijt} \geq 0 \quad (\forall i, \forall j, \forall t) \qquad (3)$$

$$Q_{ijt} = 0, (t = 8, 9, \ldots, 12) \qquad (4)$$

$$\sum_{i=1}^{2} [\, Q_{it}^{IL} + Q_{it}^{IS}\,] \leq inv^{max} \quad (\forall t) \qquad (5)$$

$$Q_{i,(t-1)}^{IL} + \sum_{j=1}^{2} Q_{i,j} - Q_{i,t}^{IL} - \alpha\, q_{i,t}^{S} = 0 \quad (\forall i, \forall t) \qquad (6)$$

$$Q_{i(t-1)}^{IS} + q_{it}^{S} - Q_{it}^{IS} = \beta\, d_{it} \quad (\forall i, \forall t) \qquad (7)$$

$$\sum_{i=1}^{2} qr_{i,t}^{S} \leq r^{\max} \quad (\forall t) \qquad (8)$$

$$\sum_{i=1}^{2} qo_{i,t}^{S} \leq O^{\max} \quad (\forall t) \qquad (9)$$

$$qr_{i,t}^{S} + qo_{i,t}^{S} - q_{i,t}^{S} = 0 \quad (\forall t, \forall i) \qquad (10)$$

The constraint set (2) guarantee that volume of log AII class and AIII class must be bigger or the same with order GF and IND considering conversion factor. Equation (3) states the volume of raw material should be bigger or the same with volume to make finished goods considering the conversion factor. The constrain set (4) implies that no purchasing in 8th to 12th month every year due to the limitation of PP to provide logs. Volume of raw material never bigger than the capacity of warehouse is stated by (5).

Then equation (6) ensures that the number of logs that are available at the end of period *t* equal to the sum of logs are available at the end of the period (*t*-1) and the total volume of purchases of raw materials for each class of logs minus the number of board production in period t which has been converted into the number of logs by multiplying the amount of number of board production to the value of the conversion board into logs, that is equal to α.

Equation (7) states total demand of finished goods in period *t* can be met from the number of boards that are available at the end of the period (*t*-1) and board production period *t*, after deducting the amount of inventory allocation board at end of period *t*. The volume of finished goods at the limit multiplied by the conversion value of finished goods to the board of βi. Equation (8) states volume of board produced in reguler time may not exceed its capacity.

ISBN: 978-988-19251-9-0
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

Volume of board produced in overtime may not exceed its capacity is indicated by (9). The constraint set (10) ensures number of board production each period is the accumulation of the number of regular and overtime production boards.

IV. The Solution Method, Numerical Example, and Analysis

The optimal solution can be obtained by solving the pre-emptive of the linear programming (LP) above. The methodology to solve the proposed model is described as follow: set the parameters model based on historical data, formulate the objectives function in the LP, formulate all the constraints of the solution model, and solve the model by using optimization software *e.g.* Lingo v.9 [16].

In order to illustrate the capabilities of the proposed-model, a numerical example has been studied. Data input was obtained from VSU and Perhutani. The condition of stock, demand and all relevant data were collected as shown in Table III, Tabel IV, and Table V.

TABLE III
THE DEMAND OF FINISH GOOD AND PRICE OF LOG

Period	Demand		Price of log	
(monthly)	GF (m^3)	Indoor (m^3)	AII (Rp/m3)	AIII (Rp/m3)
January	13.98	-	-	-
February	4.38	-	-	-
March	5.36	4.56	-	-
April	5.59	-	2,721,926	4,683,354
May	-	12.49	2,594,528	4,587,744
June	8.36	11.74	2,638,691	4,406,004
July	4.30	2.83	2,707,549	4,510,334
August	9.20	3.69	2,687,962	4,253,711
September	1.97	-	2,675,161	4,395,586
October	-	-	2,716,448	4,206,598
November	13.83	16.39	-	-
December	6.75		-	-

TABLE IV
THE INITIAL STOCK, INVENTORY COST, AND MEAN OF PURCHASING

	Initial stock (m^3)	Inventory cost (Rp/m3/year)	Mean of purchasing price (Rp/m3)
F/G -GF	4,62	-	-
F/G-IND	3,71	-	-
Board-GF	-	430,980	14,363,996
Board-IND	-	430,980	14,363,996
Log-AII	26,69	107,745	3,591,499
Log-AIII	31,62	107,745	3,591,449

TABLE V
THE CONVERSION VALUE OF FINISHED GOODS TO LOG, BOARD, AND RST

	LOG	Requirement (m3)		
	Type	Log	Board	RST
F/G -GF	AIII	5.2	2.6	1.898
	AII	20	10	7
F/G-IND	AIII	12.2	6.1	4.453
	AII	4.95	2.5	1.75

We were calculated decision variables for 1 year planning horizon. The results above are summarized in Table VI. It can be inferred that there are 6 times of procurement of log. The maximum of inventory of log will occur in 7^{th} month. In order to ensure the production, company must storage 26.50 m3 of GF board as well as 8.214 m3 of IND board.

TABLE VI
THE RESULT OF DECISION VARIABLES CALCULATION

Period	Procurement of log		Inventory of log		Inventory of board	
	AII (m^3)	AIII (m^3)	GF (m3)	IND (m3)	GF (m3)	IND (m3)
Jan.	-	35.16	-	31.138	-	3.708
Feb.	255.94	22.78	-	287.083	-	3.708
Mar.	-	57.13	29.094	271.937	-	-
Apr.	-	-	-	271.937	-	-
May	-	43.48	43.482	208.511	-	0.798
June	-	-	-	151.993	-	-
July	-	224.77	202.440	137.965	-	-
Aug.	-	-	154.621	119.680	-	-
Sept.	-	-	144.377	119.680	-	-
Oct.	-	-	91.361	119.680	26.5	-
Nov.	-	-	72.487	38.554	-	-
Dec.	-	-	37.413	38.554	-	-

We also compare the results got from the existing condition with the output of the model (Table VII). The result we got from the model yields 47% less volume of log purchased of AII and 23% less volume of AIII. This policy will decrease the cost of procurement up to 39%. For average inventory of log, the model yields 55% less and for average inventory of board, the model yields 91% less than the existing model respectively. The result of model also showed that the model can reduse total cost considered about 40.2%.

TABLE VII
THE COMPARISON OF TOTAL COST BETWEEN CURRENT AND PROPOSED MODEL

Cost	Current (IDR)	Proposed (IDR)	Saving (IDR)
Procurement of Log	3,807,109,929	2,315,450,124	1,491,659,805
Inventory of Log	51,768,962	23,093,859	28,675,103
Inventory of Board	13,968,078	1,247,022	12,721,056
Regular labor cost	140,674,100	59,148,625	81,525,475
Overtime labor cost	99,268,540	0	99,268,540
Total	4,112,789,609	2,398,939,630	1,713,849,979

V. Conclusion and Future Research

A proposed model is formulated considering procurement and inventory policies in a company of export-oriented furniture industry. The model can minimize procurement and inventory cost. A linear programming (LP) was proposed to solve this problem. The model can be used to make decisions not only the number of inventory log and board, but also the decision on procurement during a year.

Further research can be conducted more detail in procurement topic, such as alternative teak wood sourcing from community forest. Teak wood from community forest usually has lower price with lower quality, with higher availability do to it can be purchase almost along the year. With the alternative sourcing decision maker can determine the volume to buy from PP and from community forest. Goal programming and robust optimization can be considered as the alternative approaches to describe the model extensively.

ACKNOWLEDGMENT

Authors thank to Perum Perhutani, Valasindo Sentra Usaha, and ASMINDO Solo Raya for supporting this research with data and other supports. Authors also thank to Directorate General of Higher Education for "Hibah Bersaing" Program and Laboratory of Logistics and Business System, Department of Industrial Engineering, Sebelas Maret University that partly fund this research.

REFERENCES

[1] Regional Economic Development Indonesia (REDI), 2007, "Studies in Obstacles of Policy for Furniture Industry - Results of Studies in East Java and Central Java,.pdf.usaid.gov/pdf_docs/PNADN181.pdf, USAID: The United States Agency for International Development, accessed on September 5, 2011, in Bahasa Indonesia.

[2] Center for Research and Development of Climate Change Policy (Pusat Penelitian dan Pengembangan Perubahan Iklim dan Kebijakan), "Imbalances in the Value Added Distribution of Furniture Value Chain (Ketidakseimbangan Distribusi Nilai Tambah dalam Rantai Nilai [Value Chain] Mebel)", Policy Brief Vol. 4 No. 7, Badan Penelitian dan Pengembangan Kehutanan, Kementerian Kehutanan, Republik Indonesia, wrote in Bahasa Indonesia, 2010.

[3] Central Java Provincial Forestry Office (CJPFO), Official Website, (Dinas Kehutanan Propinsi Jawa Tengah / DKPJT), available at http://dinhut.jatengprov.go.id/, accessed May 24, 2011.

[4] A. O. T. Devi, Model for Determine Material Purchasing Quantity and inventory in CV. Valasindo Sentra Usaha , The Undergraduated Thesis in Industrial Engineering Department at Sebelas Maret University, Indonesia, 2010.

[5] M. Hisjam, A. D. Guritno, H. Simon, and S. D. Tandjung, "A Framework for the Development of Sustainable Supply Chain Management for Business Sustainability of Export-Oriented Furniture Industry in Indonesia (A Case Study of Teak Wooden Furniture in Central Java Province)," In *Proc. Of the 1st International Conference on Industrial Engineering and Service Science*, Indonesia, September, 2011.

[6] Yuniaristanto, W. Sutopo, and A. Aisyati, "A Facility Location-Allocation Model to Minimize Total Inbound Costs in The Rattan Furniture Industry," *Jurnal Teknik Industri*, vol 12, no. 1, pp. 17-24, 2010 (Published in Indonesian).

[7] Yuniaristanto, W. Sutopo, A. Aisyati, and P.W. Andreadi, "A Facility Location-Allocation Model for Determining Number of Depot to Distribute Material in The Rattan Furniture Industry by Considering Dynamic Demand", in *Proc. of the 11th Asia Pacific Industrial Engineering and Management Systems Conference*, Penang, Malaysia, 2010, pp 410-416.

[8] Indonesia Furniture Association (ASMINDO, 2008) "Overview of Indonesia Furniture and Handicraft Industry, Available:www.timbertradeactionplan.info-%20Indonesia.pdf. Accessed June 25, 2009.

[9] The United States Agency for International Development (USAID, 2006), EU Furniture Market Study–Summary, available: http:// pdf.usaid.gov//PNADH793.pdf. Accessed June 25, 2010.

[10] Department of Industry and Trade of Central Java Province (DP3JT), "Annual Report of the Implementation Evaluation Main Tasks and Functions", Semarang, 2005.

[11] V. Jayaraman and H. Pirkul, "Planning and Coordination of Production and Distribution Facilities For Multiple Commodity," *European Journal of Operational Research,* no. 133, pp. 394-408, 2001.

[12] T. Imamura, K. Masami K., and I. Jun, "Method for Production Planning and Inventory Control in Oil Refinery", Memoirs of the Faculty of Engineering, Okayama University, vol. 41, no. 1, pp.20-30, 2007.

[13] L. Schulze and L. Li, "Location-Allocation Model for Logistics Networks with Implementing Commonality and Postponement Strategies," in *Proc. of the International MultiConference of Engineers and Computer Scientists*, Hongkong, 2009.

[14] Y. Huang and G. Q. Huang, "Game-Theoretic Coordination of Marketing and Inventory Policies in a Multi-level Supply Chain," in *Proc. of the World Congress on Engineering*, London, U.K , 2010, pp. III. 1-6.

[15] A. Kengpol and P. Kaoien, "A Procurement Planning Improvement by Using Linear Programming and Forecasting Models" in *Proc. of 19th International Conference on Production Research*, 2007.

[16] Anonym, "Optimization Modeling with Lingo", Fifth Edition. USA: LINDO Systems Inc., 2003.

ISBN: 978-988-19251-9-0
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)