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COMPARING TRANSPORTATION COSTS BETWEEN PROCESSORS AND BUYERS IN CPO TENDER USING GENETIC ALGORITHM AND OPERATIONS RESEARCH TOOLS

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ABSTRACT

Crude Palm Oil (CPO) business has become the most important agroindustrial commodity of Indonesia, while as of 2006, Indonesia was the largest producer and exporter of CPO with 20.9 million tons. This business involves many players in a long supply chain starting from farmers and ending with the buyers, both local and abroad. One of the major costs in supply chain is transportation cost. This research tried to apply and compare Genetic Algorithm and Operations Research tools in minimizing the supply chain transportation costs between 10 CPO processors (PTPNs) and 9 CPO buyers (private companies). The better method that obtain optimum solution was Operations Research Transportation Model using North-West Corner Method with a total cost of Rp 7,047,935,664 compared to Rp 9,563,378,906 for the GA approach.

***Keywords**: Crude Palm Oil (CPO), Supply Chain, Transportation Cost, Genetic Algorithm, Operations Research*

1. INTRODUCTION

1.1 Palm Oil

Palm oil has become the most important agroindustrial commodity of Indonesia, while as of 2006, Indonesia was the largest producer of palm oil, surpassing Malaysia by producing more than 20.9 million tons. Indonesia aspires to become the world's top producer of palm oil. FAO data show production increased by over 400% within 1994-2004 to over 8.66 million metric tons. According to Hamburg-based Oil World trade journal in 2008, global production of oils and fats stood at 160 million tons. Crude Palm Oil (CPO) and Palm Kernel Oil (PKO) was jointly the largest contributor, accounting for 48 million tons or 30% of the total output.

1.2 Palm Oil Supply Chain

Palm oil industry involves many players who interact with each other, starting with the farmers and ending in the buyers (the downstream processor of CPO) and has a long supply chain. A supply chain is a system of organizations, people, technology, activities, information and resources involved in moving a product or service from supplier to customer (Chopra and Meindl, 2007).

1.3 Transportation Cost Optimization

Transportation is a very important aspect in the Supply chain. This is shown by the fact that transportation accounted for 1/3 to 2/3 of logistics costs (Ballou, 2004).

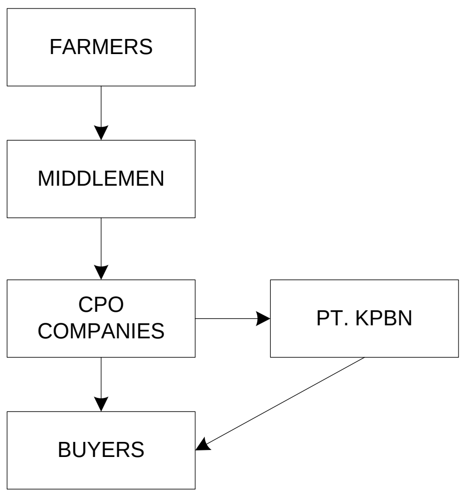

Figure 1. Palm Oil Supply chain

Meanwhile, according to Chopra and Meindl (2007), cost of logistics is about 21% of all costs in manufacturing companies. These are why the transportation became the focus of attention in many discussions about the supply chain. To achieve efficiency in supply chain transportation costs, we need a modeling tool. The first modeling tool is Operations Research (OR). As a formal discipline, Operations Research originated in the efforts of military planners during World War II. The second tool for optimization is Genetic Algorithm (GA), GA is a search heuristic that mimics the process of natural evolution.

2. LITERATURE REVIEW

2.1 Genetic Algorithm

Genetic Algorithm is a search techniques performed well on a number of possible solutions known as population (Mitchell, 1999). Individuals in a population is represented by chromosomes. This chromosome is a solution in a symbolic form. Initial population is built randomly, whereas the next population is the result of the evolution of chromosomes through iterations called generations. In each generation, chromosomes will go through the process of evolution by using a measuring tool called the fitness function. Chromosome can also be modified by using a mutation and crossing operation (crossover) (Kusumadewi. 2003).

2.2 Operations Research

OR is a scientific approach to analyzing problems and making decisions (Taha, 2007). OR professionals aim to provide rational basis for decision making by seeking to understand and structure complex situations and to use this understanding to predict system behavior and improve system performance. Much of this work is done using analytical and numerical techniques to develop and manipulate mathematical and computer models of organizational systems composed of people, machines, and procedures. There are 3 methods in finding the lowest transportation cost in Operations Research, namely Northwest-corner, Least-cost and Vogel Approximation Method (VAM). TORA Solver (Operations Research Program) may be used to find the optimum cost using the 3 methods above.

2.3 Transportation Model

The transportation model is a special class of linear programs that deals with shipping a commodity from sources (e.g., factories) to destinations (e.g., warehouses). The objective is to determine the shipping schedule that minimizes the total shipping cost while satisfying supply and demand limits. The application of the transportation model can be extended to other areas of operation, including inventory control, employment scheduling, and personnel assignment (Taha. 2007).

3. RESEARCH METHODOLOGY

This study started with developing the CPO negotiation supply chain transportation model. Afterward, this study employed two approaches, namely the GA and the OR North-West Corner. As the original distance figures used with GA gave impractical results, they were scaled down by dividing them by a factor of 250.

4. TECHNICAL ANALYSIS

4.1 Palm Oil Supply Chain Transportation Cost

The issue discussed here is the calculation of the CPO supply chain transportation cost between processor (PTPNs) and CPO buyers. There are 10 PTPNs and 9 buyers (private company). Transportation costs obtained from the multiplication of truck fuel consumption per kilometer with the distance between PTPNs and buyers. The following 10 locations and 9 buyers network is shown in Figure 2.

The data about CPO (volumes and prices) being negotiated are taken from the real on-line transactions in the website of PT Kharisma Pemasaran Bersama Nusantara (KPBN) in September 2011 (http://www.kpbptpn.co.id/). The data about distances between locations of the processors and the buyers are taken from the map of Indonesia. The location of each PTPN, buyers and its transportation model are shown in table 1, table 2, and table 3.

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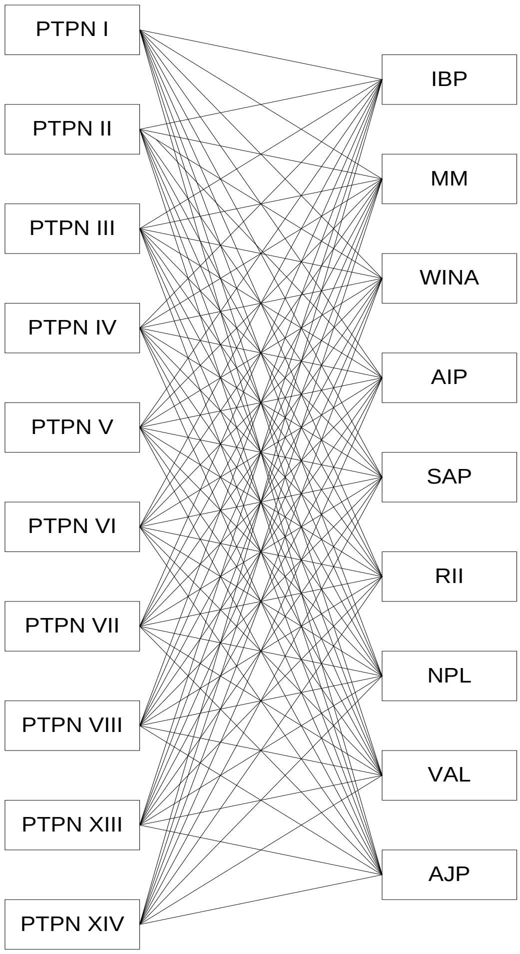

Figure 2. Palm oil supply chain network

The data about distances between locations of the processors and the buyers are taken from the map of Indonesia. The location of each PTPN, buyers and its transportation model are shown in table 1, table 2, and table 3.

Table 1. Location of buyers

No	Company Name	Code	Location	Demand CPO per day (ton)
1	Intibenua Perkasatama	IBP	Riau	1000
2	Musim Mas	MM	Medan	3500
3	Wilmar Nabati Indonesia	WINA	Medan	2250
4	Agrindo Indah Persada	AIP	Medan	500
5	Sinar Alam Permai	SAP	Medan	1000
6	Royal Industries Indonesia	RII	Karawang	2000
7	Nagamas Palmoil Lestari	NPL	Medan	3000
8	Victorindo Alam Lestari	VAL	Medan	1000
9	Agro Jaya Perdana	AJP	Medan	1000

The distances were determined using a map with a scale written on it. CPO were shipped by special tank truck, with fuel consumption estimated at 3.2 km per 1 liter of diesel fuel.

Table 2. Location of PTPNs

No	PTPN	Location	Supply CPO per day (ton)
1	I	Aceh	1000
2	II	Medan	1000
3	III	Medan	2000
4	IV	Medan	1500
5	V	Riau	2000
6	VI	Jambi	2500
7	VII	Lampung	2000
8	VIII	Bandung	500
9	XIII	Pontianak	2000
10	XIV	Ujung Pandang	750

The fuel price was set at Rp 4500/liter. The cost of shipping the CPO by sea was estimated at $20 per ton. Table 3 shows the distances from PTPN to the buyers. Example for X_{11} : the distance between PTPN 1 to PT. Inti Benua Prakastama (IBP) is 439 km, the cost is = (439km/3.2km) x Rp 4500 = **Rp 616,992**

Table 3. Distance between PTPN and buyers in KM

From/To		Company									Supply
		IBP	MM	WINA	AIP	SAP	RII	NPL	VAL	AJP	
PTPN	I	439	127	114	101	108	1416	89	105	117	1000
	II	302	39	35	31	33	1289	27	32	36	1000
	III	322	20	18	16	17	1160	14	16	18	2000
	IV	332	10	9	8	9	1044	7	8	9	1500
	V	117	410	369	328	348	879	287	340	377	2000
	VI	400	712	641	569	605	538	498	591	655	2500
	VII	819	1112	1000	889	945	207	778	923	1023	2000
	VIII	1045	1338	1204	1070	1137	68	936	1110	1231	500
	XIII	982	1274	1147	1019	1083	68	892	1057	1172	2000
	XIV	967	1260	1134	1008	1071	54	882	1046	1159	750
Demand		1000	3500	2250	500	1000	2000	3000	1000	1000	**15250**

Table 4. Transportation cost occur between PTPNs and buyers

	From/To	Company									Supply
		IBP	MM	WINA	AIP	SAP	RII	NPL	VAL	AJP	
PTPN	I	Rp 616,992	Rp 178,242	Rp 160,418	Rp 142,594	Rp 151,506	Rp 1,990,848	Rp 124,770	Rp 147,941	Rp 163,983	1000
	II	Rp 425,039	Rp 54,844	Rp 49,359	Rp 43,875	Rp 46,617	Rp 1,812,606	Rp 38,391	Rp 45,520	Rp 50,456	1000
	III	Rp 452,461	Rp 27,422	Rp 24,680	Rp 21,938	Rp 23,309	Rp 1,631,347	Rp 19,195	Rp 22,760	Rp 25,228	2000
	IV	Rp 466,172	Rp 14,063	Rp 12,656	Rp 11,250	Rp 11,953	Rp 1,468,215	Rp 9,844	Rp 11,672	Rp 12,938	1500
	V	Rp 164,531	Rp 575,859	Rp 518,273	Rp 460,688	Rp 489,480	Rp 1,236,747	Rp 403,102	Rp 477,963	Rp 529,791	2000
	VI	Rp 562,148	Rp 1,000,898	Rp 900,809	Rp 800,719	Rp 850,764	Rp 756,864	Rp 700,629	Rp 830,746	Rp 920,827	2500
	VII	Rp 1,151,719	Rp 1,563,047	Rp 1,406,742	Rp 1,250,438	Rp 1,328,590	Rp 290,692	Rp 1,094,133	Rp 1,297,329	Rp 1,438,003	2000
	VIII	Rp 1,469,833	Rp 1,881,161	Rp 1,693,047	Rp 1,504,933	Rp 1,598,990	Rp 95,063	Rp 1,316,818	Rp 1,561,367	Rp 1,730,669	500
	XIII	Rp 1,380,254	Rp 1,791,583	Rp 1,612,426	Rp 1,433,270	Rp 1,522,848	Rp 95,997	Rp 1,254,114	Rp 1,487,017	Rp 1,648,258	2000
	XIV	Rp 1,360,145	Rp 1,771,473	Rp 1,594,328	Rp 1,417,183	Rp 1,505,755	Rp 75,887	Rp 1,240,037	Rp 1,470,326	Rp 1,629,757	750
Demand		1000	3500	2250	500	1000	2000	3000	1000	1000	15250

Table 5. Genetic Algorithm solution

	From/To	Company									Supply
		IBP	MM	WINA	AIP	SAP	RII	NPL	VAL	AJP	
PTPN	I	47	302	94	9	46	154	254	46	47	1000
	II	47	303	94	9	48	153	253	47	46	1000
	III	68	324	957	0	68	174	273	68	68	2000
	IV	105	362	154	30	107	214	313	107	107	1500
	V	164	418	210	87	161	269	368	163	161	2000
	VI	214	471	260	174	213	319	421	214	215	2500
	VII	163	418	210	86	162	269	369	161	163	2000
	VIII	9	216	7	9	9	66	165	9	9	500
	XIII	162	419	208	86	162	269	370	161	162	2000
	XIV	23	267	55	9	23	114	214	23	23	750
Demand		1000	3500	2250	500	1000	2000	3000	1000	1000	15250

4.2 Objective function/fitness function and constraints

Minimize $Z = 616992X_{11} + 178242X_{12} + 160418X_{13} + 142594X_{14} + 151506X_{15} + 1990848X_{16} + 124770X_{17} + 147941X_{18} + 163983X_{19} + 425039X_{21} + 54844X_{22} + 49359X_{23} + 43875X_{24} + 46617X_{25} + 1812606X_{26} + 38391X_{27} + 45520X_{28} + 50456X_{29} + 452461X_{31} + 27422X_{32} + 24680X_{33} + 21938X_{34} + 23309X_{35} + 1631347X_{36} + 19195X_{37} + 22760X_{38} + 25228X_{39} + 466172X_{41} + 14063X_{42} + 12656X_{43} + 11250X_{44} + 11953X_{45} + 1468215X_{46} + 9844X_{47} + 11672X_{48} + 12938X_{49} + 164531X_{51} + 575859X_{52} + 518273X_{53} + 460688X_{54} + 489480X_{55} + 1236747X_{56} + 403102X_{57} + 477963X_{58} + 529791X_{59} + 562148X_{61} + 1000898X_{62} + 900809X_{63} + 800719X_{64} + 850764X_{65} + 756864X_{66} + 700629X_{67} + 830746X_{68} + 920827X_{69} + 1151719X_{71} + 1563047X_{72} + 1406742X_{73} + 1250438X_{74} + 1328590X_{75} + 290692X_{76} + 1094133X_{77} + 1297329X_{78} + 1438003X_{79} + 1469833X_{81} + 1881161X_{82} + 1693047X_{83} + 1504933X_{84} + 1598990X_{85} + 95063X_{86} + 1316818X_{87} + 1561367X_{88} + 1730669X_{89} + 1380254X_{91} + 1791583X_{92} + 1612426X_{93} + 1433270X_{94} + 1522848X_{95} + 95997X_{96} + 1254114X_{97} + 1487017X_{98} + 1648258X_{99} + 1360145X_{101} + 1771473X_{102} + 1594328X_{103} + 1417183X_{104} + 1505755X_{105} + 75887X_{106} + 1470326X_{107} + 1240037X_{108} + 1629757X_{109}$

Subject to:

$X_{11}+X_{12}+X_{13}+X_{14}+X_{15}+X_{16}+X_{17}+X_{18}+X_{19} = 1000$

$X_{21}+X_{22}+X_{23}+X_{24}+X_{25}+X_{26}+X_{27}+X_{28}+X_{29} = 1000$

$X_{31}+X_{32}+X_{33}+X_{34}+X_{35}+X_{36}+X_{37}+X_{38}+X_{39} = 2000$

$X_{41}+X_{42}+X_{43}+X_{44}+X_{45}+X_{46}+X_{47}+X_{48}+X_{49} = 1500$

$X_{51}+X_{52}+X_{53}+X_{54}+X_{55}+X_{56}+X_{57}+X_{58}+X_{59} = 2000$

$X_{61}+X_{62}+X_{63}+X_{64}+X_{65}+X_{66}+X_{67}+X_{68}+X_{69} = 2500$

$X_{71}+X_{72}+X_{73}+X_{74}+X_{75}+X_{76}+X_{77}+X_{78}+X_{79} = 2000$

$X_{81}+X_{82}+X_{83}+X_{84}+X_{85}+X_{86}+X_{87}+X_{88}+X_{89} = 500$

$X_{91}+X_{92}+X_{93}+X_{94}+X_{95}+X_{96}+X_{97}+X_{98}+X_{99} = 2000$

$X_{101}+X_{102}+X_{103}+ X_{104}+X_{105}+X_{106}+ X_{107}+X_{108}+X_{109} = 750$

$X_{11}+X_{21}+X_{31}+X_{41}+X_{51}+X_{61}+X_{71}+X_{81}+X_{91}+X_{101} = 1000$
$X_{12}+X_{22}+X_{32}+X_{42}+X_{52}+X_{62}+X_{72}+X_{82}+X_{92}+X_{102} = 3500$
$X_{13}+X_{23}+X_{33}+X_{43}+X_{53}+X_{63}+X_{73}+X_{83}+X_{93}+X_{103} = 2250$
$X_{14}+X_{24}+X_{34}+X_{44}+X_{54}+X_{64}+X_{74}+X_{84}+X_{94}+X_{104} = 500$
$X_{15}+X_{25}+X_{35}+X_{45}+X_{55}+X_{65}+X_{75}+X_{85}+X_{95}+X_{105} = 1000$
$X_{16}+X_{26}+X_{36}+X_{46}+X_{56}+X_{66}+X_{76}+X_{86}+X_{96}+X_{106} = 2000$
$X_{17}+X_{27}+X_{37}+X_{47}+X_{57}+X_{67}+X_{77}+X_{87}+X_{97}+X_{107} = 3000$
$X_{18}+X_{28}+X_{38}+X_{48}+X_{58}+X_{68}+X_{78}+X_{88}+X_{98}+X_{108} = 1000$
$X_{19}+X_{29}+X_{39}+X_{49}+X_{59}+X_{69}+X_{79}+X_{89}+X_{99}+X_{109} = 1000$
$X_{11}; X_{12}; X_{13}; \ldots; X_{109} \geq 0$
X_{ij} represent the tons of CPO shipped between PTPN i to buyer j.

4.3 Genetic Algorithm

Chromosomes representation

X11	X21	X31	X41	X51	X61	X71	X81	X91	X101
1000	1000	2000	1500	2000	2500	2000	500	2000	750

X11	X12	X13	X14	X15	X16	X17	X18	X19
1000	3500	2250	500	1000	2000	3000	1000	1000

By multiple value for each gen in the chromosome we get 5.315625 x 10^59 possible solutions

Genetic Algorithm implementation using Matlab R2008a toolbox for Genetic Algorithm steps are follows:

1. Define and create objective function/fitness function in M file
2. Encode constraints into matrix as a chromosomes representation, we convert those 19 constraints into 90 x 19 matrix
3. Define initial population
   Population size consist of 20 individuals
4. Fitness scaling
   Rank based fitness
5. Selection
   Stochastic Uniform
6. Crossover and mutation
   Single point crossover and use constraints dependent default
7. Stopping criteria are 100 iterations and infinite time limit

4.4 Solution using Genetic Algorithm

The value of objective function is **Rp 11,484,421,659**

The Genetic Algorithm CPO allocation solution doesn't feasible for the real CPO business, because it is impossible to ship only 7 tons of CPO (X83) for example from PTPN 8 to PT. Wilmar Nabati Indonesia, the minimum shipping that possible is 250 tons CPO per shipping, then we make an adjustment/modification for the constraints so that the CPO allocation only reach the number of 250 tons or its multiples.

4.5 Solution using Genetic Algorithm with adjustment

We change the supply and demand by divide it by 250, because the minimum shipment of CPO that make sense in this industry is 250 ton/shipment, so we get:

500 = 2	1500 = 6	2500 = 10
750 = 3	2000 = 8	3000 = 12
1000 = 4	2250 = 9	3500 = 14

But the result of genetic algorithm with adjustment broke the constraints, the value of objective function is **Rp 9,563,378,906**

Table 6. Results of Genetic Algorithm method with adjustment

From/To		Company									Supply
		IBP	MM	WINA	AIP	SAP	RII	NPL	VAL	AJP	
PTPN	I	0	0	250	0	0	250	500	0	0	1000
	II	0	250	250	0	250	0	0	0	0	750
	III	0	250	500	0	250	500	250	250	250	2250
	IV	0	250	250	0	250	250	500	250	0	1750
	V	500	250	250	250	0	250	250	500	0	2250
	VI	250	750	250	0	0	250	500	250	500	2750
	VII	250	500	500	0	0	250	250	0	250	2000
	VIII	0	250	0	0	0	0	0	0	0	250
	XIII	0	500	0	250	0	250	750	0	250	2000
	XIV	0	500	0	0	0	0	0	0	0	500
Demand		1000	3500	2250	500	750	2000	3000	1250	1250	15500

4.6 Solution using North-West Corner

Table 7. Result of OR North-west Corner

From/To		Company									Supply
		IBP	MM	WINA	AIP	SAP	RII	NPL	VAL	AJP	
PTPN	I			1000							1000
	II									1000	1000
	III		2000								2000
	IV		1500								1500
	V	1000		1000							2000
	VI			250	250	1000			1000		2500
	VII				250			1750			2000
	VIII						500				500
	XIII						750	1250			2000
	XIV						750				750
Demand		1000	3500	2250	500	1000	2000	3000	1000	1000	**15250**

The value of objective function is **Rp 7,047,935,664**

5. CONCLUSION

The minimum cost of CPO supply chain transportation is obtained using genetic Algorithm Method, Genetic Algorithm with adjustment and OR is shown in Table 8.

Table 8. Recap of transportation costs

Genetic Algorithm	
Rp	11,484,421,659
GA with adjustment	
Rp	9,563,378,906
Operations Research	
Rp	7,047,935,664

The best method that obtain optimum solution is Operations Research Transportation Model using North-West Corner Method. The reasons that the results shown by GA was worse than OR are:

- GA produce fraction numbers which were spread into all variables, so that the multiple factor for transportation cost is more than the result of using OR
- GA seems not suitable for this type of problem

We did not create Genetic Algorithm program, but used toolbox Genetic Algorithm on Matlab which provided standard choices of functions.
Recommendation:

- The next research can find the transportation cost for whole supply chain transportation
- Continue research on the unexpected results

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