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Contents

better life and future

OPTIMIZATION OF COCODIESEL SUPPLY CHAIN MODEL USING GENETIC ALGORITHMS

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Abstract

Genetic Algorithms search the best solutions based on the natural genetic system and the process of evolution. The best solution of Total Supply Chain Cost (TSCC) in agroindustrial supply chain model is solved by genetic algorithms efficiently and effectively. The purposes of this research are : Build the agroindustrial supply chain model based on transportation, inventory, and distribution model; Build a genetic algorithms program to optimize the agroindustrial supply chain model and see the searching efficiency of the best solution with genetic algorithms; Studying and applying genetic algorithms program that has been made for the cocodiesel agroindustrial supply chain. A result of this research shows The GASCM Ver. 1.0 program is very effective and efficient to find the best solutions of TSCC from agroindustrial supply chain model.

Key words: Genetic algorithms, TSCC, agroindustrial supply chain model, cocodiesel

1. PREFACE

Original definition of supply chain management comes from logistic management. It has been known since 1781. Logistic management is a strategic process to arrange supplies, movement, material inventory, components, product inventory (and related infomations) within organization and marketing so the profits can be maximum to fulfill the demands with an effective cost.

Nowadays, the development of knowledge and information makes a supply chain management (SCM) being an important part for company to challenges the competitive global market. The define of supply chain shows some complex networks from facility and distribution which is operate the functions of the material supply, the material transformation into a semi finished product or finished product for distributes to customers, and how to handling a quantity of inventory in agroindustry. Allocation must be controlled due to the differences of cost from a source to many destinations, and so does from many sources to a destination. The inventory cost has to be considered too.

Agroindustrial supply chain model is very complex model due to the combination of supply chain parameters. It needs a good optimization method to efficient the model. One of the newest optimization methods is Genetic Algorithms (GA). GA is a searching technique which is very robust, adaptive, and efficient that from Artificial Intelligence Science. GA search the best solutions based on the natural system like natural genetic and the process of evolution. It is very appropriate to solve complex optimization cases. The best solution of Total Supply Chain Cost (TSCC) in agroindustrial supply chain model can be solved with genetic algorithms efficiently and effectively.

Case study of this research is agroindustrial of cocodiesel supply chain model. Cocodiesel is an alternative fuel which is substitute a gasoline. Cocodiesel made from coconut oil. Cocodiesel has a low emission, high burning flame, and it was a good mono alkyl ester compound from triglyceride ester. The source of cocodiesel is very large of quantity due to the coconut fruit was spread all over the lands in Indonesia, especially near by a coast. The model will be examined, analyzed, and designed to get an optimal TSCC solutions with GA.

2. RESEARCH METODOLOGY

2.1 Idea Framework

A tight competition prosecutes a companies to use a new model for information and product flows development. Supply chain concept approaches the logistic problem as a wide problem starting from supply material until finished product to used by consumer. Therefore, a supply chain on the upstream side is a relation between suppliers - manufacturers, shift onto downstream side that are a consumers (demand). This approach is shown to a management and observation relations in coorperative for all common party who included to efficiently using the sources for consumer satisfaction. The purposes of Supply Chain Management (SCM) is to makes all system efficiently and effectively; minimize total cost from supplier, distribution, transportation, inventory, and finished product.

The emphasis of SCM problem in this research is modelling a supply chain to optimizing the Total Supply Chain Cost (TSCC) which is represented by a transportation cost, distribution cost, and inventory cost. Supply chain model formulation tooks a problem of agroindustrial supply chain, that consist of agricultural product supplier, agroindustry, and consumer (demand). Its model developed based on transportation, inventory, and distribution model with an *integer linear programming*. The purpose is to minimize a TSCC function. Case study of this reseach is optimize the TSCC agroindustrial of cocodiesel. Cocodiesel is an alternative fuel which is subtitutes a gasoline. The scenario will be examined, analysed, and designed based on secondary data.

2.2 Scientific Method Approach

The research uses the scientific method approach which is a problem solving method that see all party in the problem as a party that needed by the model itself. Scientific model is a method to solve a problem sistematically, consistently, and logically. Its consist of observation, problem identification, model construction, verification model, validation model, solutions, and implementation (Taylor, 2002).

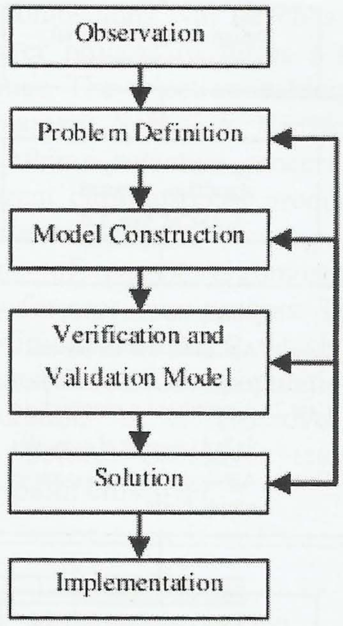

Figure 1. Scientific Method Flow Chart (Taylor, 2002)

These steps is very commonly using in the management area. In this research, the proccess will be more detailed for optimizing the agroindustrial of cocodiesel supply chain model. See the below flow chart :

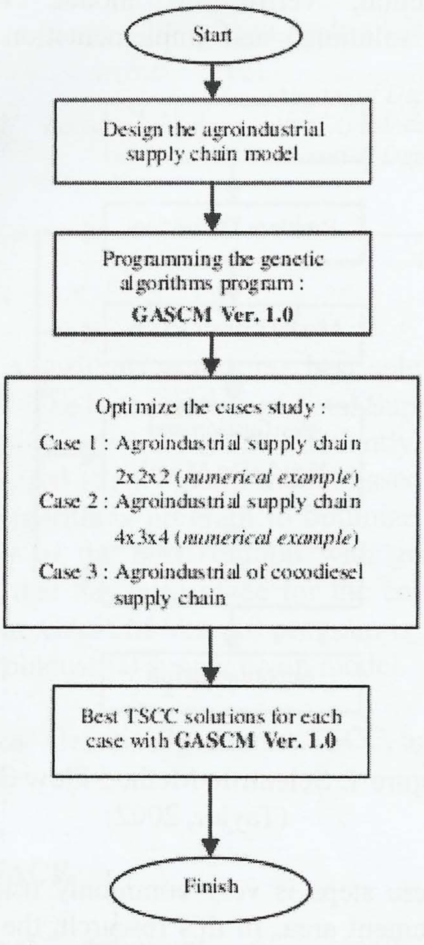

Figure 2. Research Flow Chart

3. AGROINDUSTRIAL SUPPLY CHAIN

3.1 Agroindustrial Supply Chain Model

Supply chain is a transportation, inventory, and distribution model starting from raw material until finished product to used by consumer. To build a supply chain model, it needs some steps, there are; variables assumption; decision variables identification; constraint variables identification; goal formulation; and model compilation. Its model used to find the optimal goal solution of TSCC (Total Supply Chain Cost). It represented as an Integer Linear Programming, which means the values of decision variables are positive integer numbers, not contains a fraction or decimal.

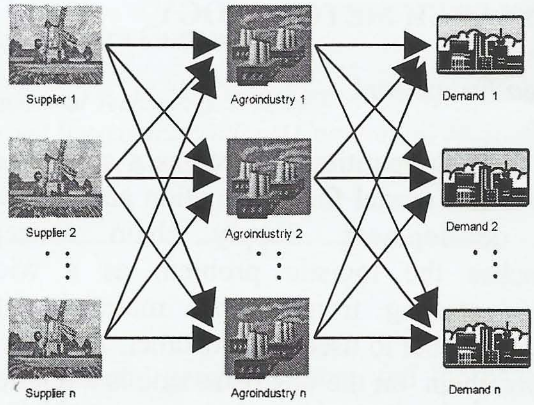

Figure 3. Agroindustrial Supply Chain Model

Based on decision, constraint, and goal variables identification results, the TSCC model of Agroindustrial SCM as follows:

$$TSCC = \sum_{i=1}^{m}\sum_{j=1}^{n} CS_{ij} S_{ij} + \sum_{j=1}^{n}\sum_{k=1}^{p} CX_{jk} X_{jk} + \sum_{j=1}^{n} CI$$

subject to :

$$\sum_{j=1}^{n} S_{ij} \leq Capa\_cS_j, \ \forall_i$$

$$\sum_{k=1}^{p} X_{jk} \leq Capa\_cX_j, \ \forall_j$$

$$I_j = Capa\_cX_j - \sum_{k=1}^{p} X_{jk}, \ \forall_j$$

$$\sum_{j=1}^{n} X_{jk} = D_k, \ \forall_k$$

3.2 Case 1 : Agroindustrial SCM 2x2x2

This case is an agroindustrial supply chain case consists of 2 suppliers, 2 agroindustry, and 2 demands (numerical example). The TSCC model of 2x2x2 supply chain as follows:

$$TSCC = 20S_{11} + 16S_{12} + 17S_{21} + 18S_{22} + 17X_{11} + 20X_{12} + 21X_{21} + 17X_{22} + 18I_1 + 19I_2$$

subject to

$$S_{11} + S_{12} \le 20$$
$$S_{21} + S_{22} \le 30$$
$$X_{11} + X_{12} \le 25$$
$$X_{21} + S_{22} \le 20$$
$$I_1 = 25 - X_{11} + X_{12}$$
$$I_2 = 20 - X_{21} + X_{22}$$
$$X_{11} + X_{21} = 22$$
$$X_{12} + X_{22} = 14$$

A decision variable will be represented as a gene in the chromosome. The representation is in Figure 4 as below:

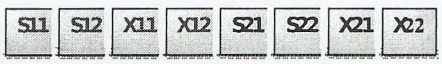

Figure 4. Chromosome representation of agroindustrial supply chain 2x2x2

Genetic Algorithms parameter values in this case are:

- Crossover Probability (Pc) = 0,9
- Mutation Probability (Pm) = 0,05
- Populations Size (PopSize) = 20
- Maximum Generations (MaxGen) = 600

```
This output is written at: 6/2/2007  9:24:24 AM
========================================
          INITIAL REPORT
       Optimization with GAs
     AGROINDUSTRIAL SCM 2X2X2
========================================

GAs parameters
==============
Pop. Size             = 20
Chrom. Length         = 8
Max. Generation       = 600
Crossover probability   = 0.9000
Mutation probability    = 0.0500

INITIAL GENERATION STASTISTICS
==============================
    S11 S12 X11 X12 S21 S22 X21  X22  I1  I2          TSCC
---------------------------------------------------------------
  1)  0  18  16   7  25   2   6    7   2   7      1575.0000
  2) 13   5  14   7  12  15   8    7   4   5      1646.0000
  3)  3  14  12  11  22   6  10    3   2   7      1620.0000
  4)  3  16   9  11  22   4  13    3   5   4      1625.0000
  5)  9   9  17   6  16  11   5    8   2   7      1613.0000
  6)  0  16  20   1  25   4   2   13   4   5      1543.0000
  7) 14   3  13   4  11  17   9   10   8   1      1644.0000
  8)  6  10  11   6  19  10  11    8   8   1      1620.0000
  9) 14   3  18   4  11  17   4   10   3   6      1629.0000
 10)  9   9   9   9  16  11  13    5   7   2      1649.0000
 11)  9   8  10   8  16  12  12    6   7   2      1644.0000
 12) 16   2  10   7   9  18  12    7   8   1      1673.0000
 13)  8   8  21   3  17  12   1   11   1   8      1588.0000
 14) 13   4   8  10  12  16  14    4   7   2      1678.0000
 15) 11   6  16   1  14  14   6   13   8   1      1608.0000
 16) 11   7  17   0  14  13   5   14   8   1      1599.0000
 17)  7  11  16   6  18   9   6    8   3   6      1606.0000
 18)  1  16  22   2  24   4   0   12   1   8      1544.0000
 19)  3  15  16   8  22   5   6    6   1   8      1594.0000
 20) 18   1  14   4   7  19   8   10   7   2      1657.0000
---------------------------------------------------------------

Sum of Fitness = 32355.0000
Max. Fitness   =  1678.0000
Min. Fitness   =  1543.0000
Avg. Fitness   =  1617.7500
```

Figure 5. Initial population on Case 1

After initial population formed, each chromosome-q within population will be evaluated using the fitness value. The fitness value is a TSCC value. A gene in the chromosome is a value of the decision variable which is calculates into TSCC function.

The next step is a chromosome selection. A pair of chromosomes will be chosen randomly for crossover process to forms a new pair of chromosomes. The selection technique that used is a Tournament Selection. Crossover process happened after a selection process which is a pair of parent chromosomes produce a pair of offspring chromosomes.

A pair of parent chromosomes has a probability for crossover process. The crossover probability in this case is 0,9, which means there is an expected 90% of new population formed on next generation is a crossover result of generation before. Crossover technique used here is one point crossover.

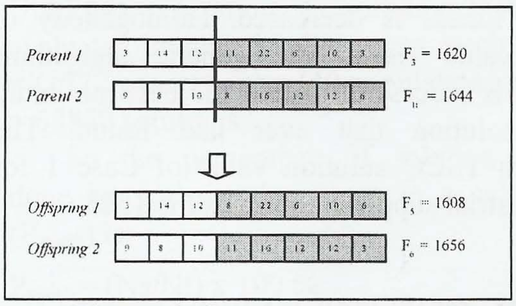

Figure 6. Crossover process on Case 1

After crossover process happened, the next probabilities that will be happen is mutation process. It will be happen if a random number that activated by computer less or same as with a mutation probability. The mutation probability in this case is 0.05, which means 5% of chromosomes in a new population will get mutation process. Mutation only happens in gen within the chromosomes.

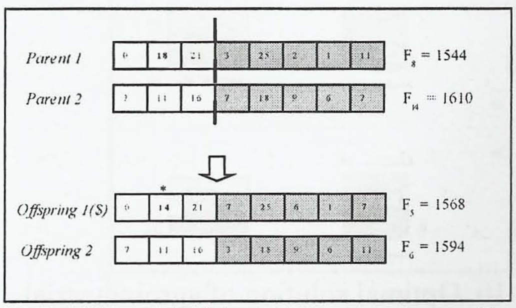

Figure 7. Mutation process on Case 1

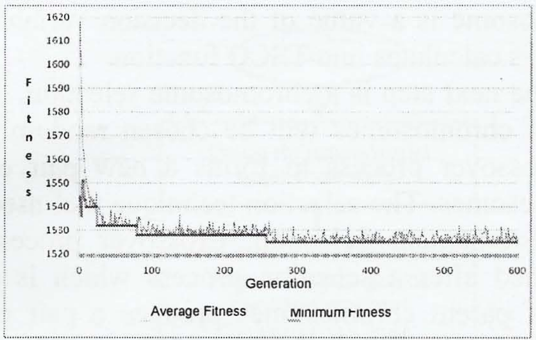

Figure 8. Average fitness and minimum fitness each generation on Case 1

The decreasing of minimum and average fitness happens on 85th generation. Minimum fitness starting convergent on 269th with the value is 1528. From 270th until 600th generation, the fitness value is always convergent and average fitness is decreased. Homogeneity of fitness value shows the genetic algorithms iteration is successful to find the best minimum TSCC solution that ever had found. The minimum TSCC solution value of Case 1 for agroindustrial supply chain 2x2x2 is 1525.

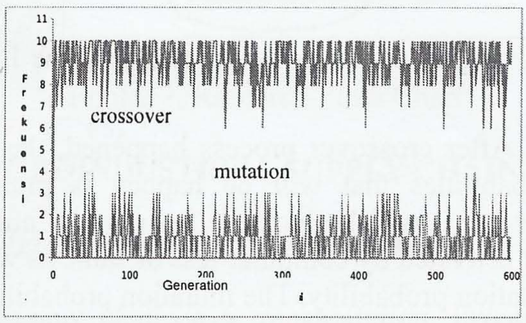

Figure 9. Crossover and mutation frequency each generation on Case 1

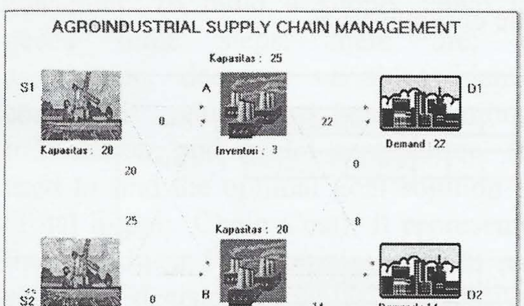

Figure 10. Optimal solution of agroindustrial supply chain 2x2x2

Total solutions within search space (Nt) for case 1 is 154.000 solutions. Optimal solution was found for the first time on 270th generation. Until this generation, the solutions that has been evaluated by genetic algorithms reach (Ns): Ns = (270 generation) x (20 population/generation) = 5400 solutions.

So the percentage of solution searching done by genetic algorithms in a search space (P_{search}) is:

$$P_{search} = (Ns/Nt) \times 100\ \%$$

$$= (5400/154.000) \times 100\ \% = 3{,}5\ \%$$

The percentage shows that genetic algorithms just explore only 3,5% of searching space to find the best TSCC solution. It is proven that a genetic algorithm is very efficiently to find an optimal solution in case 1.

3.3 Case 2: Agroindustrial SCM 4x3x4

This case is a bigger scale of agroindustrial supply chain case. It consists of 4 suppliers, 3 agroindustries, and 4 demands (numerical example). The TSCC model of 4x3x4 supply chain as follows:

$$TSCC = 17S_{11}+18S_{12}+15S_{13}+18S_{21}+15S_{22}+16S_{23}+ 18S_{31}+15S_{32}+16S_{33}+16S_{41}+14S_{42}+17S_{43}+14X_{11}+ 24X_{12}+20X_{13}+19X_{14}+21X_{21}+20X_{22}+22X_{23}+21X_{24}+ 24X_{31}+18X_{32}+20X_{33}+ 19X_{34}+15IA+10IB+13IC$$

subject to

$$S_{11} + S_{12} + S_{13} \le 31$$
$$S_{21} + S_{22} + S_{23} \le 25$$
$$S_{31} + S_{32} + S_{33} \le 34$$
$$S_{41} + S_{42} + S_{43} \le 20$$
$$X_{11} + X_{12} + X_{13} + X_{14} \le 35$$
$$X_{21} + X_{22} + X_{23} + X_{24} \le 25$$
$$X_{31} + X_{32} + X_{33} + X_{34} \le 40$$
$$I_1 = 35 - X_{11} + X_{12} + X_{13} + X_{14}$$
$$I_2 = 25 - X_{21} + X_{22} + X_{23} + X_{24}$$
$$I_3 = 40 - X_{31} + X_{32} + X_{33} + X_{34}$$
$$X_{11} + X_{21} + X_{31} = 22$$
$$X_{12} + X_{22} + X_{32} = 26$$
$$X_{13} + X_{23} + X_{31} = 25$$

$X_{14} + X_{24} + X_{34} = 20$

A decision variables will be represented as a genes in the chromosome. The representation is in Figure 11 as below :

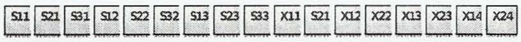

Figure 11. Chromosome representation of agroindustrial supply chain 4x3x4

Genetic Algorithms parameter values in this case are:

- Crossover Probability (Pc) = 0,9
- Mutation Probability (Pm) = 0,05
- Populations Size (PopSize) = 40
- Maximum Generations (MaxGen) = 2500

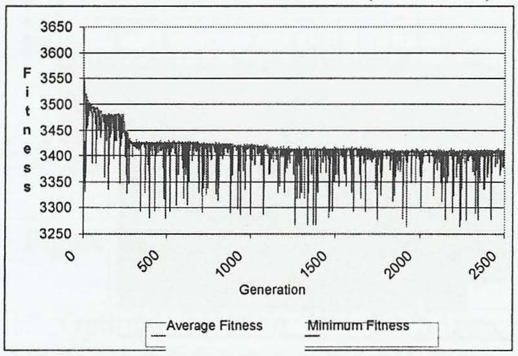

Figure 12. Average fitness and minimum fitness each generation on Case 2

The decreasing of average and minimum fitness happens from the beginning of generation until 110th generation. Its fitness value is 3478. And then it is decreasing again on 120th generation until 280th generation with 3424 of fitness value. A slope decreasing starts from 200th generation until 1721th generation and then reach the convergent from 1722th until maximum generation with fitness value is 3408. Optimal TSCC solution on case 2 is 3408.

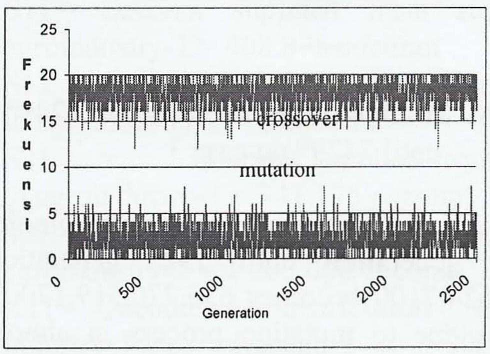

Figure 13. Crossover and mutation frequency each generation on Case 2

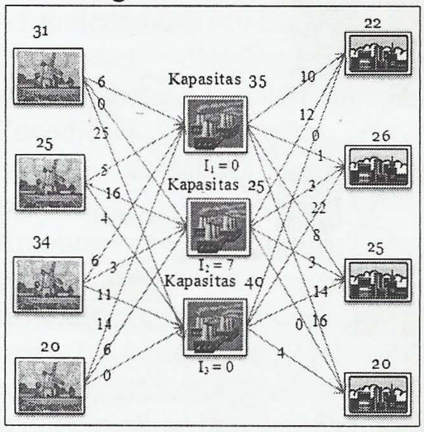

Figure 14. Optimal solution of agroindustrial supply chain 4x3x4

Total solutions within search space (Nt) for case 2 is 3,5 x 10^{24} solutions. Optimal solution was found for the first time on 1722th generation. Until this generation, the solutions that has been evaluated by genetic algorithms reach (Ns) : Ns = (1722 generation) x (40 population/generation) = 68880 solutions.

So the percentage of solution searching done by genetic algorithms in a search space (P_{search}) is:

$P_{search} = (Ns/Nt) \times 100\ \%$

$= (68880/3{,}5 \times 10^{24}) \times 100\ \%$

The percentage on case 2 will results a very small value. Its value proven that genetic algorithms will be more efficiently if the search space larger.

3.4 Case 3 : Agroindustrial of cocodiesel supply chain

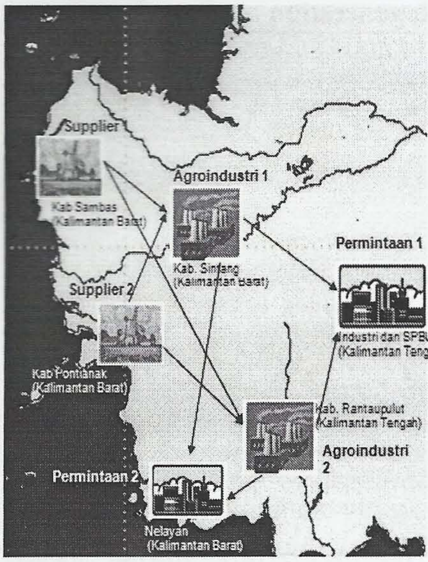

Figure 15. Agroindustrial of cocodiesel supply chain scenario

The first coconut supplier (Supplier-1) is in Sambas sub-province area (West Kalimantan) and the second supplier (Supplier-2) is in Pontianak sub-province area (West Kalimantan). For the cocodiesel agroindustry-1 is in Sintang sub-province area (West Kalimantan) and the cocodiesel agroindustry-2 is in Rantaupulut sub-province area (Middle Kalimantan). The first demand for cocodiesel is for a fisherman in coastal area of Karimata strait (West Kalimantan) and the second demand is for industries and gasoline stations/SPBU in Middle Kalimantan area.

The TSCC model of this case designed as follows:

$$TSCC = 206.27S_{11} + 299.15S_{12} + 194.66S_{21} + 194.66S_{22} + 123.22X_{11} + 169.66X_{12} + 123.22X_{21} + 152.25X_{22} + 300I_1 + 400I_2$$

subject to

$$S_{11} + S_{12} \leq 647.875$$
$$S_{21} + S_{22} \leq 1.341.167$$
$$X_{11} + X_{12} \leq 750.000$$
$$X_{21} + X_{22} \leq 1.000.000$$
$$I_1 = 750.000 - X_{11} + X_{12}$$
$$I_2 = 1.000.000 - X_{21} + X_{22}$$
$$X_{11} + X_{21} = 500.000$$
$$X_{12} + X_{22} = 1.000.000$$

Chromosome representation for case 3 as follows :

S11	S12	X11	X12	S21	S22	X21	X22

Figure 16. Chromosome representation of agroindustrial of cocodiesel supply chain

Genetic Algorithms parameter values in this case are:
Crossover Probability (Pc) = 0,9
Mutation Probability (Pm) = 0,05
Populations Size (PopSize) = 40
Maximum Generations (MaxGen) =15.000

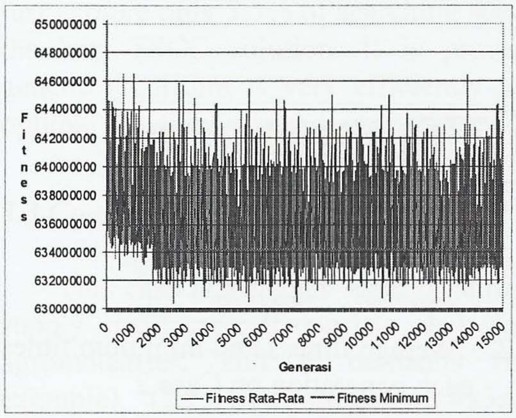

Figure 17. Average fitness and minimum fitness each generation on Case 3

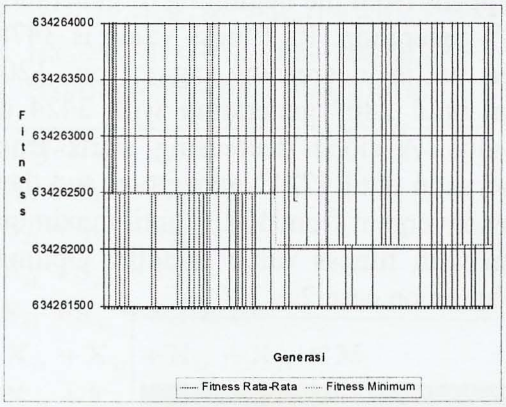

Figure 18. Minimum fitness chart from 7249th until 7429th on case 3

A minimum fitness start decreasing from the beginning generation until 132th generation (650,394,624.7100 becomes 636,770,519.1700). It happens due to mutation process in almost population. A slope decreasing of fitness value from 133th until 1723th due to mutation and crossover process and reach 634,262,491.5400. After that generation the fitness looks like convergent. But it seen there are decreasing of fitness value on 7329th from 634,262,491.5400 becomes 634,262,038. 7500. A minimum fitness starts convergent from 7344th until maximum generation with value 634,262,038.7500.

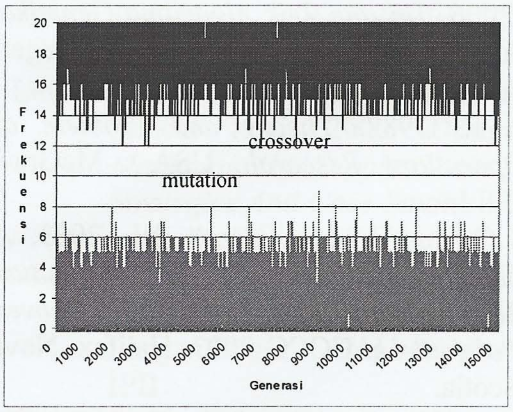

Figure 19. Crossover and mutation frequency each generation on Case 3

Optimal solution has been reached from 7344th generation with TSCC value is 634,262,038.7500. Below are the values of decision variables:

S11 = 408875 X11 = 500000 I1 = 250000
S12 = 0 X12 = 0 I2 = 0
S21 = 341125 X21 = 0
S22 = 1000000 X22 = 1000000

Decision variables value (11, X12, X21, X22, I1, and I2) will be converted from each-item coconut bases into a liter cocodiesel bases. One liter cocodiesel is equal with five item cococodiesel. Therefore the decision variables values are:

S11 = Coconut supplied from supplier-1 to agroindustry-1 = 408.875 coconut
S12 = Coconut supplied from supplier-1 to agroindustry-2 = 0 coconut
S21 = Coconut supplied from supplier-2 to agroindustry-1 = 341.125 coconut
S22 = Coconut supplied from supplier-2 to agroindustry-2 = 1.000.000 coconut
X11= Cocodiesel distribution from agro industry-1 to demand-1 = 100.000 liter cocodiesel
X12 = Cocodiesel distribution from agro industry-1 to demand-2 = 0 liter cocodiesel
X21 = Cocodiesel distribution from agro industry-2 to demand-1 = 0 liter cocodiesel
X22= Cocodiesel distribution from agro industry-2 to demand-2 = 200.000 liter cocodiesel
I1 = Amount of cocodiesel inventory in agroindustry-1 = 50.000 liter cocodiesel
I2 = Amount of cocodiesel inventory in agroindustry-2 = 0 liter cocodiesel

Total solutions within search space (Nt) for case 3 is 3,75 x 10^{23} solutions. Optimal solution was found for the first time on 7329th generation. Until this generation, the solutions that has been evaluated by genetic algorithms reach (Ns) : Ns = (7329 generation) x (40 population/generation) = 293160 solutions. So the percentage of solution searching done by genetic algorithms in a search space (P_{search}) is:

$$Psearch = (Ns/Nt) \times 100\ \%$$
$$= (293160 / 3{,}75 \times 10^{23}) \times 100\ \%$$

The percentage on case 3 will results a very small value. Its value proven that genetic algorithms will be more efficiently if the search space larger. The optimal solution that has been found by genetic algorithms on case 3 is very efficient.

4. CONCLUSION AND SUGGESTION

4.1 Conclusion

Supply chain is a transportation, inventory, and distribution model starting from raw material until finished product to use by consumer. Agroindustrial supply chain model in this research consists of three tiers that are supplier, agroindustry, and consumer (demand). The model will be optimal if it has a good combination of parameters to get a minimum TSCC (Total Supply Chain Cost). Its combination is a searching problem to optimize the TSCC within the search space.

One of the newest optimization methods is genetic algorithms (GA). GA is a searching technique which is very robust, adaptive, and efficient that from Artificial Intelligence Science. GA search the best solutions based on the natural system like natural genetic and the process of evolution. GA is used in this research to optimize TSCC model.

Implementation of this research is designing a GASCM (Genetic Algorithms for Supply Chain Management) Ver 1.0 program that made by Boland Delphi 7.0. It based on Simple Genetic Algorithms (SGA) and has been developed from its functions and procedures within the program, which are: FitFunc function to calculate TSCC model; InitPop is population initialization with integer representation to fulfill a constrains; Select function is a function to select a chromosome with a tournament selection method; and statistic procedure developed into graphics form.

The result of this research shows that GASCM Ver 1.0 very efficiently to find a minimum TSCC solution from agroindustrial supply chain. On case 1 (agroindustrial SCM 2x2x2), the minimum solution has been reached at 270th generation with the value of TSCC 1525. Genetic Algorithms only explore 3,5% of searching space to find the best solution on case 1. It will be more efficient if the search space is larger. It has been proven on case 2 (agroindustrial SCM 4x3x4) and case 3 (Agroindustrial of cocodiesel supply chain).

4.2 Suggestion

Some suggestions needed for further research about genetic algorithms in agroindustrial supply chain cases as follows:

1. Need more further studies about population quantity, and maximum generation influences to get an optimal solution
2. Need a new method like elitism (ranking adjustment based on fitness value) for a faster performance of genetic algorithms
3. In this research, genetic algorithms optimization is only have a single objective (to minimize TSCC) case, for the further development can be applying for a multi objective case.

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