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OPTIMIZATION OF REVERSE LOGISTICS NETWORK FOR END-OF-LIFE/SECOND HAND MOTORCYCLE IN THAILAND *

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1. Introduction

Currently, the benefit gained from the collected product and the end-of-lease has also become more concerned as a business strategy. For motorcycle industry, Thailand is one of the countries that have the largest number of motorcycle populations and its number still keeps growing. Nevertheless, when a motorcycle become End-of-Life vehicle, the number of damped or scraped motorcycles is yet still unknown and some motorcycles are end up as a remnant of iron regardless its potential to be able to recycle which also caused the environmental problem and more materials are needed for manufacturing. In developed country, there is regulation of producer responsibility to wasted product at the end-of-life but there is no regulation about motorcycle recycling in Thailand but from the draft law by Pollution Control Department, the feasibility of this regulation is feasible.

Logistics of motorcycle in Thailand is still traditional style where the motorcycles are directly delivered from factory to each dealer. Once the motorcycles are delivered to dealers the transported trucks are returning back empty which is called "Empty back hauling". This causes unnecessary travel cost and the load factor is highly reduced. For second hand market, there is one second hand motorcycle centre established for supporting second hand motorcycle collection. However, most of collected second hand motorcycles were from the nearby area and accounted only 2% for the whole number of sold motorcycles.

Reverse logistics is the key to deal with the problem of uncollected End of life/Second hand vehicle. By using distribution centre, the logistics system efficiency will be more improved and transportation cost will be reduced. This distribution centre is also used as a collection centre which is so called "Hybrid distribution/collection centre". With this closed loop system, demand for second hand motorcycle can be more covered and also reducing the problem of empty back hauling which increases the load factor of the truck. Furthermore, as mentioned above, if the regulation is imposed, reverse logistics will be suit to handle with.

As a closed loop supply chain problem, to find the optimal location of these Hybrid distribution/collection facilities, end-of-life/second hand motorcycle demand is required. Therefore, the purpose of this study is to estimate the end-of-life/second hand motorcycle demand then design the network for closed loop logistics for motorcycle industry in Thailand as a facility allocation problem. Normally, the demand can be estimated from the number of scraped vehicle and number of vehicle by ages, however the data is not sufficient because in Thailand the record was started in 2006 which is not accurate enough. Thus, Cohort Method is used for forecasting the future demand. For facility allocation optimization of the closed loop supply chain network, in this study, then Genetic Algorithm is used for determining the optimal allocation of Hybrid distribution/collection centre.

2. Literature review

Closed loop supply chain is mainly classified into two problem types: Facility allocation and truck routing optimization problem.

*Keywords: reverse logistics, recycle, motorcycle, facility location, facility network, end of life vehicle, Genetic Algorithm

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As Facility allocation problem, for reverse logistics of End-of-life vehicle (ELV) Reynaldo Cruz-Rivera, *et al*[1] perform the network design of the collection of End-of-life vehicles in Mexico. The problem is considered as recovery network problem. The scenarios were divided by demand coverage and use Lagrangian relaxation to optimal the number and locations of facilities for End-of-life vehicle collection. Akshay Mutha, *et al*[7] developed the model that consists of multi echelon, the scenarios were set by different quantities of the products and also variation in capacity and recycling percentage. As routing optimization problem, in automotive field, there is some study about closed-loop supply chains. Frank Schultmann, *et al*[6] studied about automotive industry which described about process for recovering the plastic from ELVs which assures the feasibility of closed loop supply chain in motorcycle industry. However, the study is about vehicle routing planning which the relevant about model cannot be determined.

Among most of study about reverse logistics network, Genetic algorithm is mostly used for optimizing the network. Hyun Jeung Ko, *et al*[3] used Genetic Algorithm for integrated forward/reverse logistics network for 3PLs. The results showed that by using Genetic Algorithm, the solutions were close to the optimal solution and were able to solve the large model. G. Kannan, *et al*[2] also developed closed loop supply chain network model by utilizing Genetic Algorithm. The solution revealed that the proposed methodology performed well in terms of both quality of solutions and computational time. Farzad Dehghanian, *et al*[8] designed the tire recovery network by using Multi-objective genetic algorithm which optimize maximize economic and social benefit while minimize negative environmental impacts simultaneously.

About motorcycle recycling feasibility, N. Uesugi, *et al*[5] described about motorcycle recycling in Asia and Brazil also the topic related to the disposal of motorcycle. It was shown the material that can be recovered from End of Life motorcycle in percentage per volume and it was also shown that the disposal of motorcycles in Asia and other developing countries will become larger issue in the near future. However, there are many studies about closed-loop supply chain and end-of-life vehicle collection but there is no study about motorcycle collection network which is different from automobile. Therefore this study is aim to design the closed loop supply chain network for motorcycle industry in Thailand. As a methodology, Genetic Algorithm are used because less calculation time and quality of solutions.

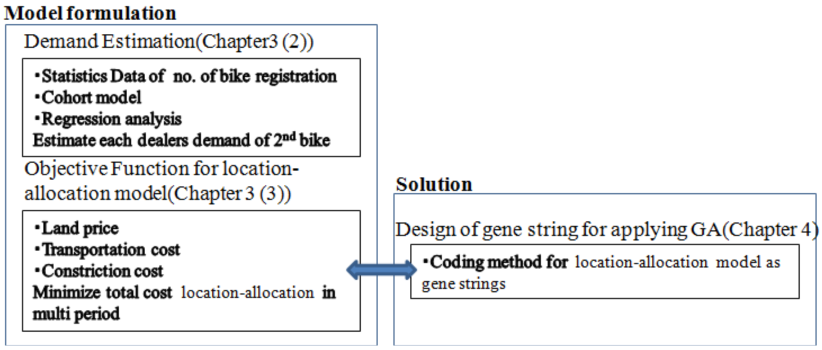

Figure 1: The study flow diagram

Relationship of our proposed model for a location-allocation problem for reverse logistics in Thailand and its solution in this study is shown in Figure 2. The rest of the paper is organized as follows: in Chapter 3, the details about model formulation demand estimation and methodology are described. The coding method of Genetic Algorithm is explained in Chapter 4 and the results and discussion are given in Chapter 5. Finally, the paper is concluded in Chapter 6.

3. Model formulation and methodology

(1) Closed loop supply chain model for motorcycle industry in Thailand

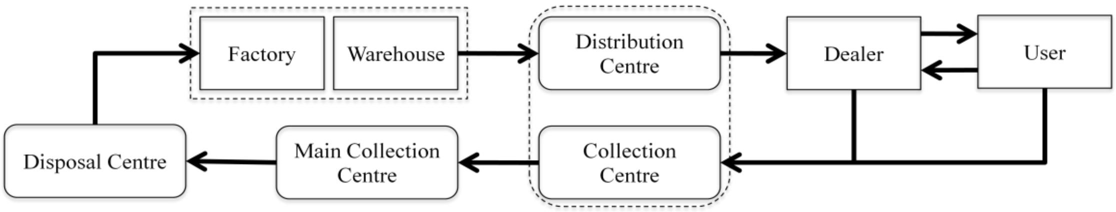

Figure 2: Conceptual model diagram

In this study, even the objective is to collect the end-of-life/second hand motorcycle, the model is considered not only recovery loop but as a closed loop to enhance the efficiency for both forward and reverse flow. In figure 1, the conceptual model diagram has been developed based on the field survey and interview. Basically, the motorcycle are manufactured then stored in the warehouse before being transported to each dealer. Apart from the traditional system, the motorcycles are then delivered to Distribution centre to distribute the motorcycles to the dealer in nearby area. In addition, on the return trip, the trucks also collect the End-of-life/second hand motorcycle back to Hybrid distribution/collection centre which can alleviate empty backhauling problem. Nonetheless, now the quantities of End-of-life/second hand motorcycle are still unknown.

To estimate the number of the End-of-life/second hand motorcycle demand regardless the number of scraped motorcycle is unknown, Cohort Method was hence introduced to forecast the number of possible End-of-life/second hand motorcycles. Then, Genetic Algorithm is used to determine the optimal number and location of the facilities. For the scope of study, this study considers only product flow from factory to customer then the product flow from the user back to main collection centre. Currently exist dealers, factory and main collection centre were utilized in this study while the disposal centre location and product flow to disposal location are not considered.

(2) End-of-life/Second hand motorcycle demand prediction by using Cohort method

Since the number of End-of-life/Second hand motorcycles is unknown, in this study, Cohort method was introduced in this study to estimate the number of end-of-life vehicle in each coming year. As expressed in the below equation, the relation between the number of registered vehicle and survival rate α_n, are shown in the equation.

$$\mathrm{P_t} = (\mathrm{P_{t-1}} + \mathrm{N_t}) - \left(\mathrm{N_{t-1}} + \sum_{n=1}^{n} \propto_n \mathrm{N_{t-n-1}}\right) + \sum_{n=1}^{n} \propto_n \mathrm{N_{t-n}} - \left(\mathrm{S_t} + \mathrm{C_{per,t}} + \mathrm{C_{temp,t}}\right) + \mathrm{T_t} \tag{1}$$

Where

t	: year
n	: vehicle age
N_t	: New registered vehicle in year *t*
α_n	: Survival rate of vehicle at age *n*
T_t	: Vehicle that possession transferred to other user in year *t*
P_t	: Number of vehicle that are being possessed in year *t*
S_t	: Vehicle that registration suspended in year *t* due to being unable to pay the tax for consecutive 3 years, enacted in year 2004
$C_{per,t}$	: Vehicle that registration was inquired to cancel from user permanently in year *t*
$C_{temp,t}$	: Vehicle that registration was inquired to cancel from user permanently in year *t* temporarily

Statistic data from Department of Land Transport, Thailand[9)] were used to find the proper survival rate. In fact, there is data about vehicle recorded by vehicle age, however the record was started in year 2006, so the data is not sufficient to utilize for exact demand estimation. To fit the curve, the different percentage between statistic number and estimated number of motorcycle that is being possessed is minimized by firstly using the only available number of vehicle by ages to find the survival rate α which obtained as listed in the table 1, the minimum average percentage difference between statistic and estimated data was 1.8%.

From year 2003 to 2004, there is a sudden drop of number of motorcycles that is being possessed because in year 2004 the regulation that for user who did not pay the tax for consecutive 3 years the registration will be suspended was first legislated. This number of suspended motorcycle was defined as S_t. In addition, in year 2004 the number of possession that was transferred to other user was first recorded which make the curve fitting become more accurate.

Comparing number of new registered motorcycle and GDP, it shows that GDP and the number of new registered motorcycle are directly proportional. In figure 5 the relation was fitted in logarithm terms with square of the correlation coefficient (R-Square) of 0.5703. The available GDP data is provided until year 2015 by International Monetary Fund (IMF), however the period of study is planned to be until 2040, the GDP is hence predicted in second order function as shown in figure 6. By using the logarithm relation between number of new registered motorcycles-GDP and forecasted GDP, the estimated number of new motorcycle is shown in figure 7. As a result, survival rates were then used to calculate the demand of second hand/end-of-life motorcycles. The demand in year t, D_t can be calculated by the following relation.

$$D_t = \sum_{n=1}^{7} (1 - \alpha_n) N_{t-n} \tag{2}$$

By substituting $\beta_n = 1-\alpha_n$

$$D_t = \sum_{n=1}^{7} (\beta_n) N_{t-n} \tag{3}$$

Then, the estimated demand are divided to each potential area i by
Demand of area i at period t:

$$D_{it} = \left(\frac{\sum N_{it}}{\sum N_t} \right) \times D_t \tag{4}$$

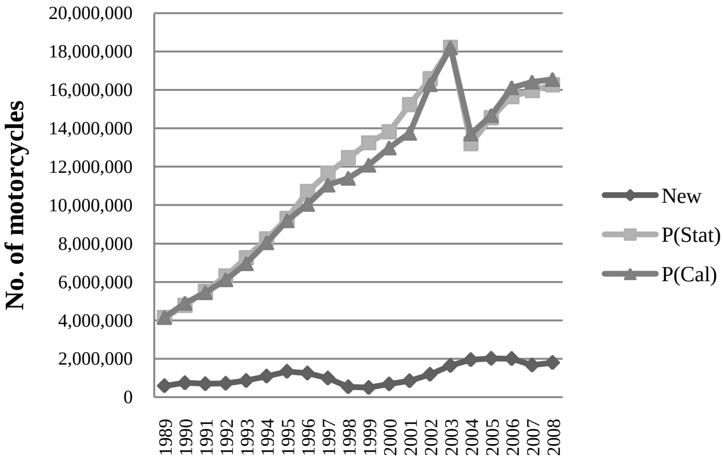

Figure 3: Estimated P_t compared with Statistical P_t

Table 1: Survival rate

Survival rate α_n		$1-\alpha_n$
α_1	1	0
α_2	0.95	0.05
α_3	0.85	0.15
α_4	0.85	0.15
α_5	0.8	0.2
α_6	0.8	0.2
α_7	0.7	0.3

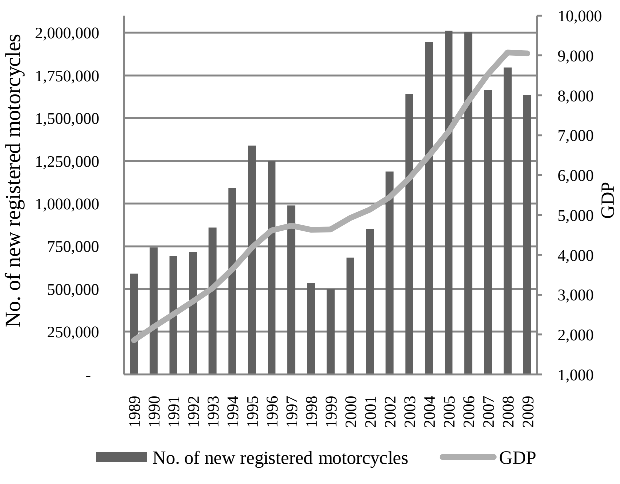

Figure 4: GDP and no. of new motorcycle relation

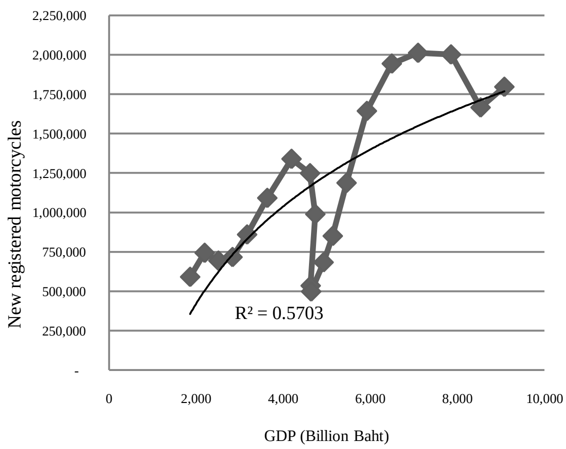

Figure 5: Number of new registered motorcycle and GDP correlation

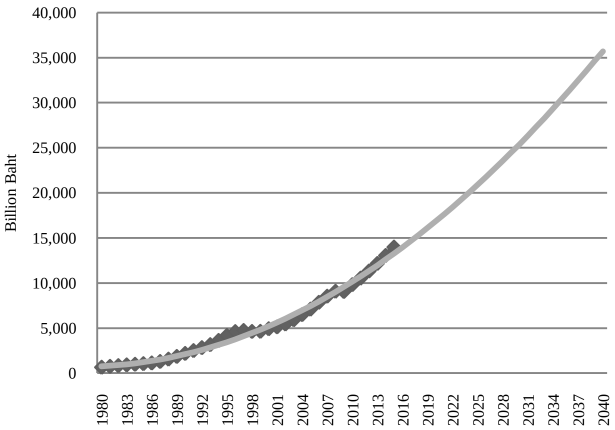

Figure 6: Estimated GDP curve

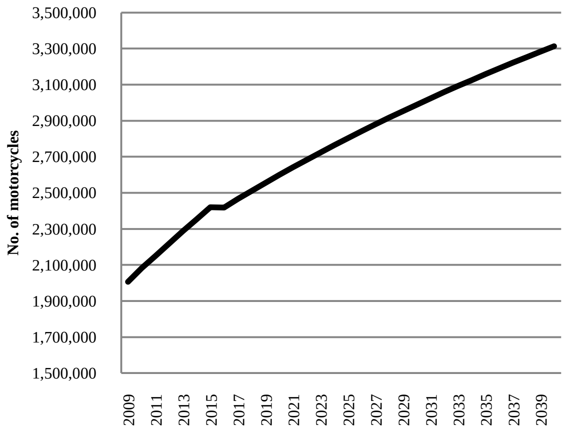

Figure 7: Predicted number of new registered motorcycle

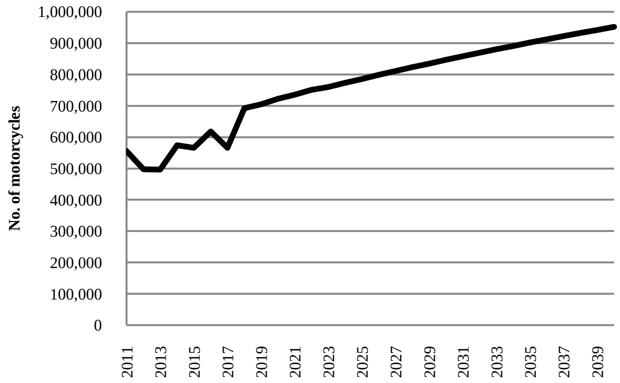

Figure 8: Predicted 2nd Hand/End-of-life motorcycle

(3) Facility location and supply chain management problem

For objective function, the model is based on the concept by Salema, *et al* [4] that the model is two-level model: in forward flow, the decision variables between factory and distribution centre ($X^{f_1}_{wdt}$) and the decision variables between distribution centre and each dealer ($X^{f_2}_{dst}$) are independent. In reverse flow, the decision variables between dealer and collection centre ($X^{r_1}_{sct}$) and the decision variables between collection centre and main collection centre ($X^{r_2}_{cC_0t}$) are also independent. With this design, the calculation times are reduced comparing with one-level model because the numbers of decision variables are reduced. Besides, this model is design as a multi-period model. Since the availability of data is in city level, the predicted demand was divided into 76 data by the percentage of sale of each city by using (4), due to the predicted demand is related to the number of new registered motorcycle as mentioned in (1).

Objective function
Minimize total cost

$$\sum_{t\in T}\sum_{d\in D} T_{wd}X^{f_1}_{wdt} + \sum_{t\in T}\sum_{d\in D}\sum_{s\in S} T_{ds}X^{f_2}_{dst} + \sum_{t\in T}\sum_{s\in S}\sum_{c\in C} T_{sc}X^{r_1}_{sct} + \sum_{t\in T}\sum_{c\in C} T_{cC_0}X^{r_2}_{cC_0t} + \sum_{i\in I} C_iY_i + \sum_{t\in T}\sum_{i\in I} f_tY_i \tag{5}$$

Subject to

$$X^{f_1}_{wdt} \geq X^{f_2}_{dst} \tag{6}$$
$$X^{r_1}_{sct} \geq X^{r_2}_{cC_0t} \tag{7}$$
$$X^{f_1}_{wdt} + X^{r_1}_{sct} \leq u_i \tag{8}$$
$$X^{r_2}_{cC_0t} \leq u_{C_0} \tag{9}$$

$$Y_i \in \{0, 1\}, \quad \forall i \tag{10}$$

Where

T_{wd}	: Transportation cost per unit from factory *w* to distribution centre *d*
$X^{f_1}_{wdt}$	: Frequency of forward transported product from factory *w* to distribution centre *d* at period *t*
T_{ds}	: Transport cost per unit from distribution centre *d* to dealer *s*
$X^{f_2}_{dst}$	: Frequency of forward transported product from distribution centre *d* to dealer *s* at period *t*
T_{sc}	: Transport cost per unit from dealer *s* to collection centre *c*
$X^{r_1}_{sct}$	: Frequency of returned product from dealer to collection centre *c* at period *t*
T_{cC_0}	: Transport cost per unit from collection centre *c* to main collection centre C_0
$X^{r_2}_{cC_0t}$	: Frequency of returned product from collection centre to main collection centre C_0 at period *t*
C_i	: Construction cost for Hybrid distribution/collection facility *i*
f_t	: Operation cost for Hybrid distribution/collection facility at period *t*
Y_i	$= \begin{cases} 1, & \text{if Hybrid distribution/collection facility is opened at } i \\ 0, & \text{otherwise} \end{cases}$
u_i	: Maximum capacity for Hybrid distribution/collection facility *i*
u_{C_0}	: Maximum capacity for main collection centre C_0
I	: The number of potential locations with *i* = 1, 2, …, *I*
TC	: Truck capacity

In this objective function, the forecasted demand was utilized by transform to trip frequency as the following relation.

$$\text{Frequency } X = \frac{\text{Forecasted demand } D}{\text{Truck capacity } TC} \tag{11}$$

For the transportation cost, T_{wd}, T_{ds} and T_{sc} are derived by

$$\text{Transportation cost} = \left(\text{Fuel cost}\left(\frac{\text{THB}}{\text{km}}\right) + \text{employee cost}\left(\frac{\text{THB}}{\text{km}}\right)\right) \times \text{shortest distance(km)} \tag{12}$$

The fuel required for each location *i* and employee cost were collected from field survey while distance to location are determined from Dijkstra method. The transportation costs were classified into 3 because the large lorry truck is used for delivery from warehouse to distribution/collection centre while small truck is used for delivery from distribution/collection centre to dealer. In equation 13, the Construction cost expressions are presented. For the land price, the data are provided by The Treasury Department of Thailand while the facility construction cost and area were collected from field survey.

$$\text{Construction cost} = \left(\text{Area}(\text{m}^2) \times \text{Land price}\left(\frac{\text{THB}}{\text{m}^2}\right)\right) + \text{Cost for facility construction} \tag{13}$$

In the objective function, the first and second terms refer to the transportation cost for the forward product flow while third and forth terms are the transportation cost for the reverse flow. The construction cost and operation cost of the hybrid distribution/collection centre are included in the rest of the objective function. The constraint (6) and (7) define the flow conservation. For the constraint about facility capacity, (8) and (9) refer to limit the product flow not to exceed the capacity of Hybrid distribution/collection facility and main collection centre respectively.

4. Coding method for applying Genetic Algorithm

First of all, the chromosome and gene strings must be defined as design variables for this location allocation problem. This cord structure is essential because it finally decides total number of combination and gives effect to an optimized result by GA. In this study, the size of design variable is depended on the total number of location choice set. For example, if the total number of distribution center is *M*, then the gene string length will be *M*. And chromosome as design variables are from 1 to *N*, where n is number of potential location for distribution center. Figure 9 shows the case of 4 destitution center. Here, gene strings structure which consists with 4 design valuables.

4 facilities case: Gene string

1-n	1-n	1-n	1-n

Figure 9: Coding of gene string

In each block means design variables, the input numbers are all feasible location number. If the network has N potential location then the possible variables will be N^M. By utilizing Genetic Algorithm, the initial population set is generated randomly. After the gene strings are selected, the value of objective function changed to fitness function for standardizing for cross over as GA process. In case same distribution center appear in one gene string which is the design values are duplicated, penalty function will be applied to avoid in the GA selection process. For the next generation, the values can change by either crossover or mutation to improve the fitness value.

5. Case study

(1) Thailand network

About motorcycle industry in Thailand, the total number of cities is 76 with the total number of dealers of 974 shops. Figure 6 shows Thailand road network, the factory and warehouse are located together at industrial site in Ladkrabang, east suburb of Bangkok while main collection centre is located at the main office in Samutprakarn, located in south region from Bangkok however since the large number of dealers, the location of whole dealers could not be shown in this figure. The Thailand road network used in this study consists of 1506 nodes and 2102 links but in this case study, the potential location has 76 locations due to the limitation of the data and constraints about geographic. Figure 6 shows route from factory to each city which was determined by Dijkstra method.

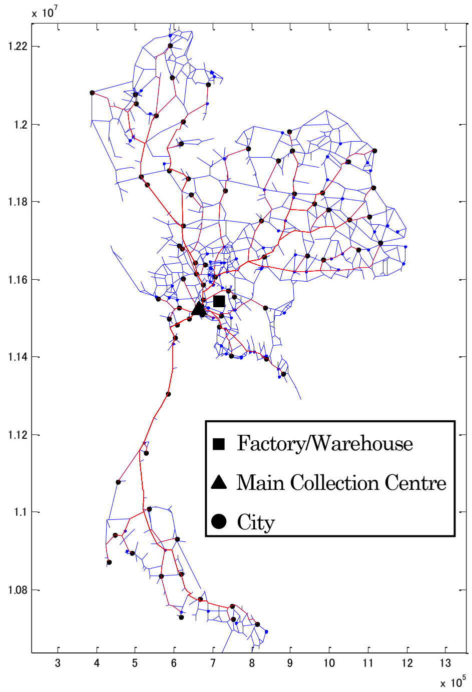

Figure 10: Thailand road network, location of factory/warehouse, main collection centre and city location

(2)Parameters in Genetic Algorithm

For GA optimization, the required parameters are set as follows. Firstly, for the crossover rate, it is set to 0.8 which make the gene become more variety. For the population size, after multi-attempt for calculation 100 were set for this function since the calculation is not high and the value of fitness function value is not different. The number of generation is normally at 150 however if there is no change in fitness value which is called Stall generation for 40, the iteration will be terminated. Another way that the program will be terminated is that when the rate of change in fitness value reaches the defined value, in this program it is set at 1×10^5. For the boundary of the selection, only the potential location can be selected to the chromosome and penalty function also used to prevent the data in chromosome become duplicated.

Table 2: Required parameter value for Genetic Algorithm

Parameter name	Value
Cross over rate	0.7, 0.8
Population size	100, 150
Number of generation	150
Stall generation	40
Limited rate of change	1×10^5

(3) Results

a) Genetic Algorithm (GA) and comparison with Monte Carlo method

For results obtained my GA, the results are divided into different scenarios by varying the number of hybrid distribution/collection centre. The iteration were terminated when the rate of change in Fitness value were less than the defined value or the number of iteration reach the number of generation that was defined.

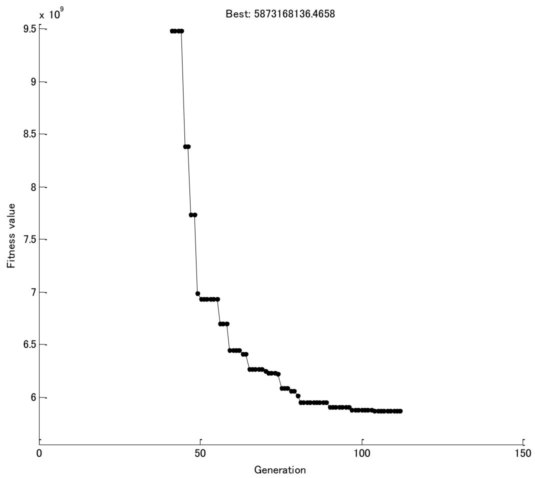

Figure 11: Fitness function against number of generation plot

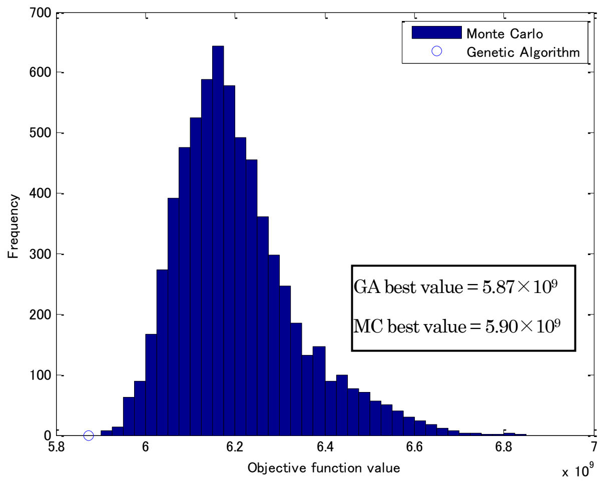

Figure 12: Distribution of value from random input and optimal value obtained by GA

At first generation the fitness value is high due to random input values, but, by using selection, crossover and mutation, the fitness value became more decreased. The iterations were repeated until rate of changes in fitness value was less than the specified value (for default value, 1×10^{-6}), in this case the optimization was finished at 112th generation.

In order to verify whether the results are optimal solution or not, Monte Carlo method was applied. From the figure 12, by normal random for 6720 iterations which is the same number of iteration in GA, the optimal solution could not yet be determined. Besides, the probability of the function value from random input to get the optimal value is relatively low. Furthermore, for this Monte Carlo method, the feasible minimum value is still higher than the optimal value obtained by GA. This shows that GA can determine the optimum value that is close to real optimum value, moreover in shorter calculation time.

b) Analysis

By performing the optimization, scenarios were attempted by increasing the number of facilities and in each scenario the optimization was performed 20 times to find the optimum point. The dot line in figure 13 refers to transportation cost for the base case where distribution centre is not established. In the figure, the number of facilities of 39 was found to be the optimum point for this network. Figure 14 represents more details about the cost when number of facilities is 39 comparing with base case in each year. It can be obviously seen that the benefit caused by the reduction of transportation cost can be gained for the whole period. Even though at year 2011 the initial construction cost are required, but the cost will be regained from these benefits. The figure 15 illustrates the estimation of the accumulated profit respect to time and it has shown that the cost will be regained in year 2019. Figure 16 illustrates the location of Factory/Warehouse, Hybrid distribution/collection centre and location of 76 cities also the area covered by each distribution/collection facility.

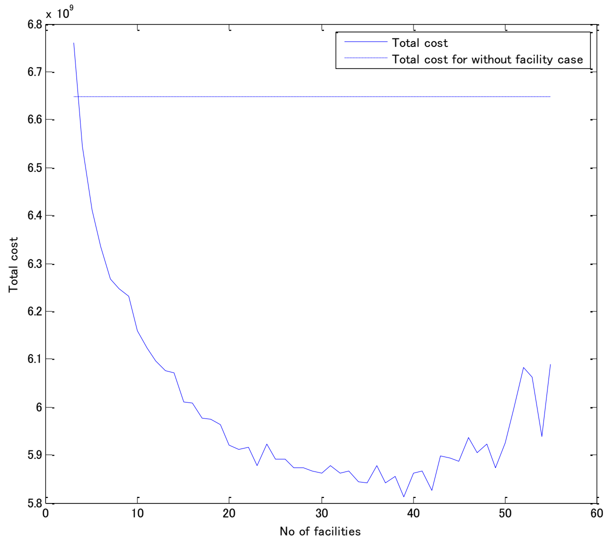

Figure 13: Total cost for different facilities configuration

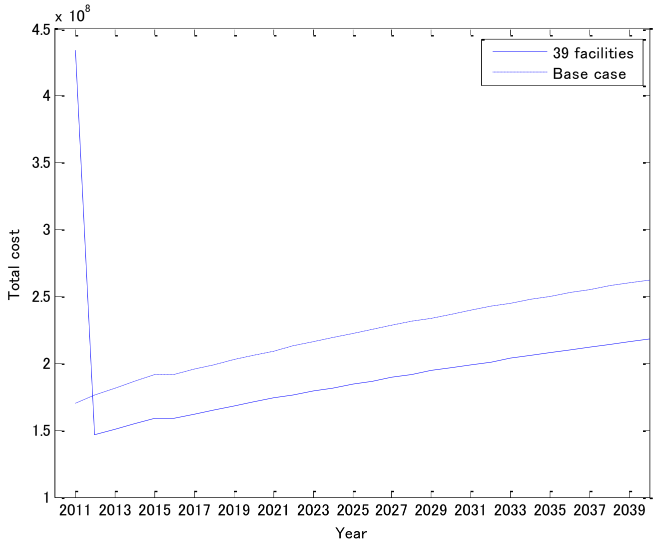

Figure 14: Total cost in each year

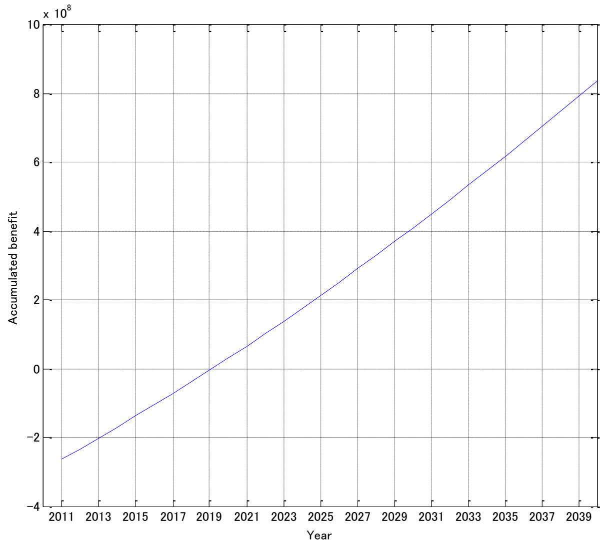

Figure 15: Profit estimation curve

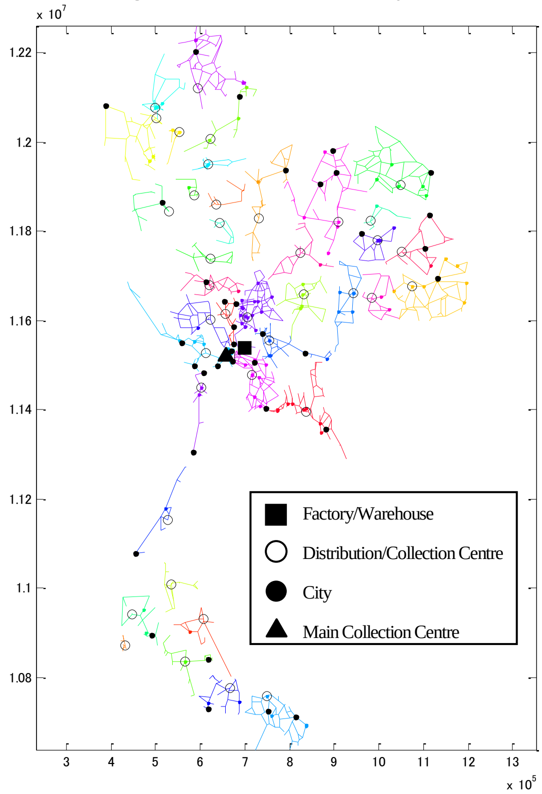

Figure 16: Area coverage by each Distribution/Collection centre

6. Conclusion and further study

Firstly, this study performed the number of End-of-life/second hand forecasting by using cohort method since the data about vehicle age is not sufficient. The results obtained by Cohort method shows that the estimated value is not much different from the statistical data which means that the predicted results are reliable. For the issue about closed loop supply chain, the problem is classified as Facility allocation problem. Since the model is NP-Hard problem, Genetic Algorithm was used for solution because of its accuracy and less time consumption. The results show that the optimal number of Hybrid distribution/collection centre is at 39 and the results also show that even though high initial costs are required, the benefits can be recovered from the reduced transportation cost in 2020. In order to assure whether the solution is reliable and close to optimal solution or not, the results obtained by using Genetic Algorithm were compared with results obtained by Monte Carlo method and the results verified that results from Genetic Algorithm are reliable and close to optimal solution

As future issue, the route between Distribution Centre and dealer is still direct route between the Hybrid distribution/collection centre and dealer therefore a method for truck routing like Traveling Salesman Problem can be applied to the model for more cost reduction and enhance the optimal solutions to the actual optimal solutions. In addition, multi-objective Genetic Algorithm such as social benefit and environmental impact as performed by Farzad Deghanian, et al[8] can be applied. Since the demand in this problem is considered as deterministic, for further study stochastic or fuzzy logics should be added to make the model become more robusted. Last but not least, in objective function the benefit gained from the collected product can be added for better solutions.

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Optimization of reverse logistics network for End-of-life/second hand motorcycle in Thailand *

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This paper presents a closed loop supply chain model for motorcycle in Thailand. Firstly, the demand of future second hand motorcycle and number of End-of-life vehicle is forecasted by using Cohort method then the network is optimized by using Genetic Algorithm in various scenarios to obtain the optimal number and location of facilities. By using Genetic Algorithm, in comparison with Monte Carlo method, the results showed reliable output. In addition, when distribution centre is introduced to the network, the travel cost is decreased but increased in construction cost. However, this introduced system may be suitable for long term planning.
