Closed-loop supply chain network optimization for Thailand motorcycle industry

SCS-10-011
Jirapat PHORNPRAPHA[1], Atsushi FUKUDA[2], Mikiharu ARIMURA[3]

[1]Graduate School of Science & Technology, Department of Transportation Engineering & Socio-technology
Nihon University
Telephone +81-47-469-5355, Fax. +81-47-469-5355
E-mail: bondjirapat@gmail.com

[2]College of Science & Technology, Department of Transportation Engineering & Socio-technology
Nihon University
Telephone +81-47-469-5355, Fax. +81-47-469-5355
E-mail: fukuda.atsushi@nihon-u.ac.jp

[3]College of Science & Technology, Department of Transportation Engineering & Socio-technology
Nihon University
Telephone +81-47-469-5355, Fax. +81-47-469-5355
E-mail: arimura.mikiharu@nihon-u.ac.jp

Abstract

Nowadays the concerning issue about environment and benefit of product at the end-of-life, Closed-loop supply chain has become more interested. Thailand is one the countries that has high population of motorcycles. In this study, the objective is to design closed-loop supply chain where both forward and reverse product flow are optimized to find the optimal location of the facility. Since there is no available data about scraped vehicles, Cohort method was to estimate the number of end-of-life motorcycles. Then, as a solution method, due to problem is classified as a NP-hard problem, Genetic Algorithm was chosen to find the optimal location where the cost is minimum.

Keywords: Closed-loop supply chain 1, Reverse logistics 2, End-of-life vehicles 3, Facility network design 4

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.

However, 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 there is no available data. 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. 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.

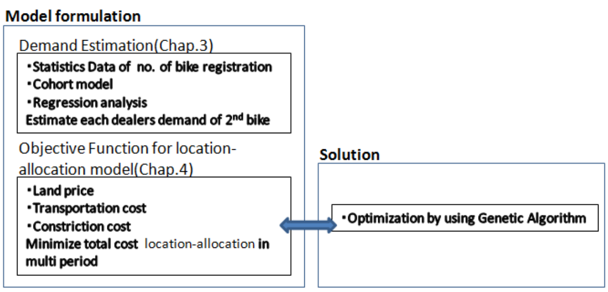

Fig. 1 The study flow diagram

Relationship of our proposed model for a location-allocation problem for reverse logistics in Thailand and its solution in this study is shown in fig. 1. The rest of the paper is organized as follows: in Chapter 3, the details demand estimation and demand assignment are described. The closed-loop supply chain model is explained in Chapter 4 and the results and discussion are given in Chapter 5. Finally, the paper is concluded in Chapter 6.

3. Demand estimation

Firstly, in order to optimize the closed-loop supply chain network, demand is essential. Normally, for the second hand/end-of-life vehicle can be estimated from the number of vehicles by ages which recorded by the department of land transportation however, the data record was just started at year 2006 which is not sufficient to be used for demand estimation. To deal with this problem, Cohort method was introduced to estimate the second hand/end-of-life vehicle demand. The equation (1) was developed to find the survival rate based on Thailand motorcycle registration system.

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

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

Cper,t : Vehicle that registration was inquired to cancel from user permanently in year *t*

Ctemp,t: Vehicle that registration was inquired to cancel from user permanently in year *t* temporarily

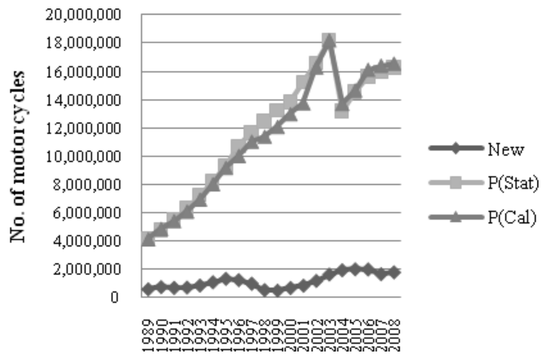

Fig. 2 Estimated P_t compared with Statistical P_t

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

The survival rates were firstly defined by trial and error then the estimated and statistical numbers of vehicle that are being possessed were compared to determine the error. The error was minimized by using solver. Then the obtained survival rates are shown in table 1. Fig. 2 shows the comparison between estimated value and statistical number of vehicle that are being possessed with minimum error. It can be noticed that in year 2004, the number dropped rapidly. This can be explained that the vehicle that user did not pay the tax for consecutive 3 years registration was suspended. The overall percentage area for this graph is 1.8%.

As the next step, to determine the number of second hand/end-of-life motorcycle, the number of new registered motorcycle is also needed to be forecasted. Fig. 3 shows the relation between the GDP and number of new registered motorcycles, it shows that these numbers are directly proportional. In fig. 4, the plot was created to find the relation between these two numbers. By fitting the logarithm function, the predicted numbers of new registered vehicle are plotted in fig 5.

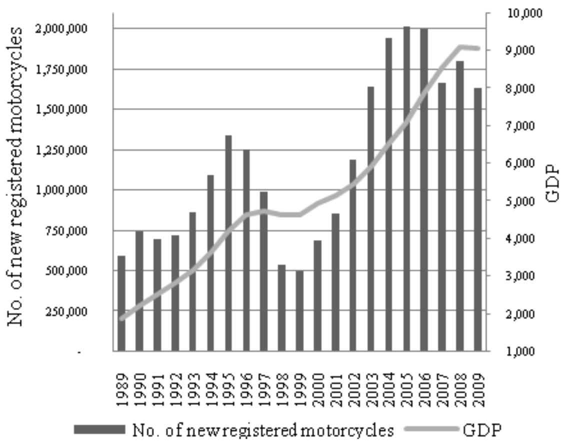

Fig. 3 GDP and no. of new motorcycle relation

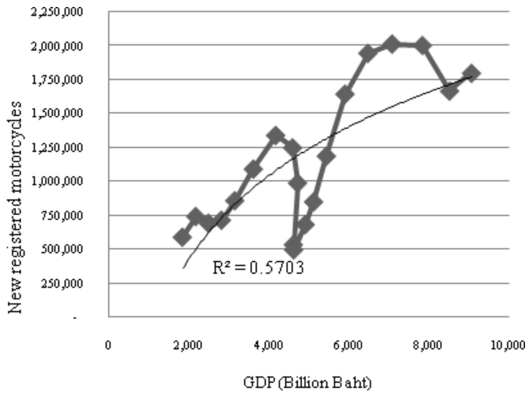

Fig. 4 Number of new registered motorcycle and GDP correlation

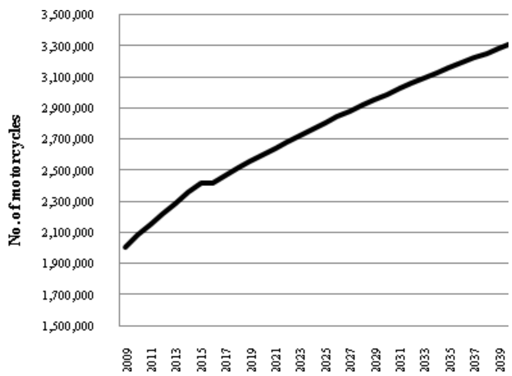

Fig. 5 Predicted number of new registered motorcycle

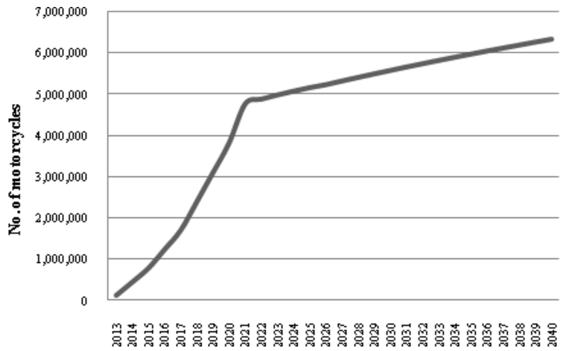

Fig. 6 Predicted 2nd Hand/End-of-life motorcycle

After the number of new registered motorcycle is predicted equation (2) is used to find second hand/end-of-life motorcycle in each year. Then the demand is divided into each area by fraction of number of new registered motorcycle as shown in equation (3) because the demand is related with the number of new registered motorcycle as expressed in equation 1.

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

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

4. Closed-loop supply chain model for motorcycle industry in Thailand

By conducting field survey and interview, fig. 7 was developed to show the concept of the closed-loop supply chain model.

Fig. 7 Conceptual model diagram

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. This design reduces the calculation time comparing with one-level model. By utilizing fig. 7, the multi period objective function was developed as shown in equation 5.

Objective function

Minimize

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

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* at period *t*

$X^{f_2}_{dst}$: 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*

$$Y_i = \begin{cases} 1, & \text{if Hybrid facility is opened at } i \\ 0, & \text{otherwise} \end{cases}$$

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*

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. The trip frequency can be determined by divide the demand by truck capacity and transportation costs are obtained from interview and field survey.

5. Results and discussion

By using Genetic Algorithm, fig. 8 shows the results from varying the number of the Hybrid distribution/collection facility, the optimal number of Hybrid distribution/collection centre was found to be 39. In fig. 9, the plot represents the total cost required in case of 39 facilities comparing with traditional case. This plot shows that the benefit can be gained from the reduced cost each year. In fig. 10 the optimal location and area coverage by Hybrid distribution/collection facility are presented.

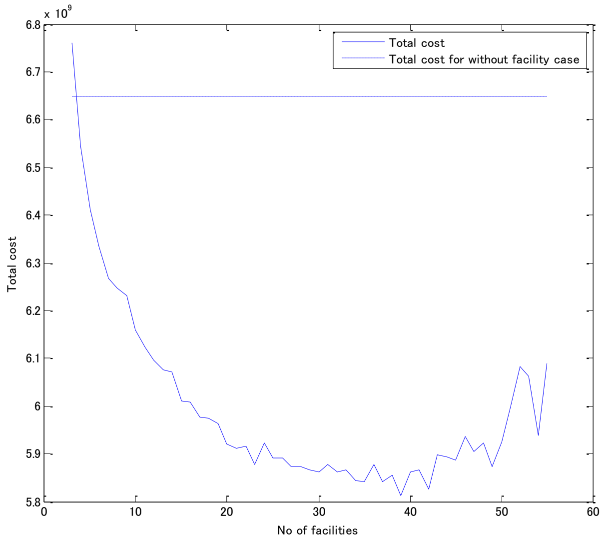

Fig. 8 Total cost for different facilities configuration

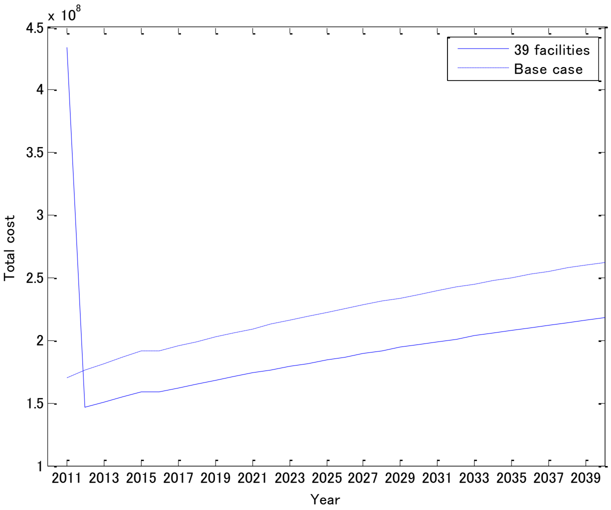

Fig. 9 Total cost in each year

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. 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.

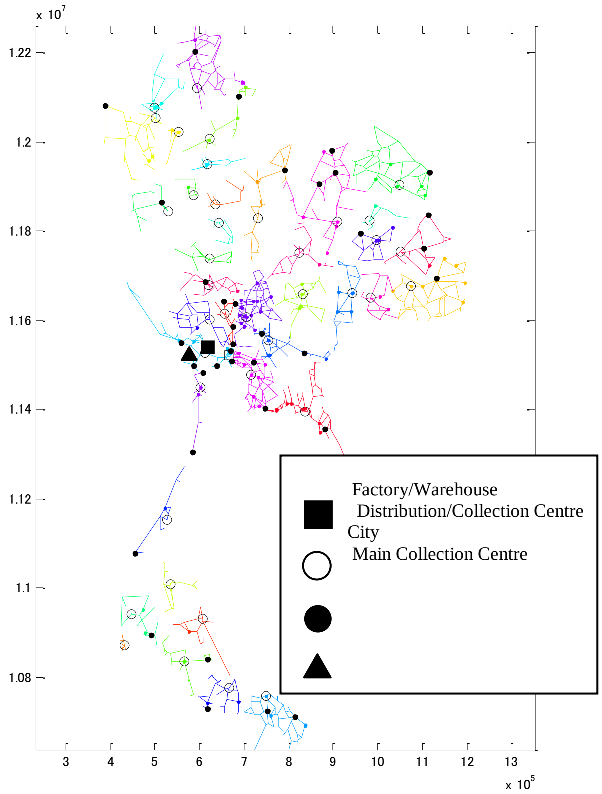

Fig. 10 Area coverage by each Distribution/Collection centre

6. Acknowledgment

The authors would like to express their sincere thanks to A.P. Honda, Second hand motorcycle centre (A.P. Honda), HMLT and Thai Honda Manufacturing Co., Ltd. for providing valuable information and data which is essential to this study.

References

[1] Reynaldo Cruz-Rivera and Jürgen Ertel (2009) Reverse logistics network design for the collection of End-of-Life Vehicles in Mexico, *European Journal of Operational Research 196*, pp.930-939.

[2] G. Kannan, P. Sasikumar and K. Devika (2009) A genetic algorithm for solving a closed loop supply chain model: A case of battery recycling, Applied Mathematical Modelling (2009), doi: 10.1016/j.apm.2009.06.021

[3] Hyun Jeung Ko, Gerald W. Evans. (2007) A genetic algorithm-based heuristic for the dynamic integrated forward/reverse logistics network for 3PLs, *Computers & Operations Research 34*, pp.346-366.

[4] MI Salema, APB Póvoa and AQ Novais (2006) A warehouse-based design model for reverse logistics, *Journal of the Operational Research Societ*y 57, pp.615-629.

[5] Naomoto Uesugi, Toshio Yamagiwa and Yoshihiko Tatemichi (2004) Motorcycle Disposal and Recycling in Asia and Brazil, *IATSS Review*, Vol.29, pp.229-237.

[6] Frank Schultmann, Moritz Zumkeller and Otto Rentz (2006) Modeling reverse logistics tasks within closed-loop supply chains: An example from the automotive industry, *European Journal of Operational Research 171*, pp.1033-1050.

[7] Akshay Mutha and Shaligram Pokharel (2009) Strategic network design for reverse logistics and remanufacturing using new and old product modules, *Computer & Industrial Engineering 56*, pp.334-346.

[8] Farzad Deghanian and Saeed Mansour (2009) Designing sustainable recovery network of end-of-life products using genetic algorithm, Resources, *Conservation and Recycling 53*, pp.559-570.

[9] Department of Land Transport (Ministry of Transport), Thailand.