2011 Ninth International Conference on ICT and Knowledge Engineering

A Mixed Integer Non-linear Programming Model for Optimizing the Collection Methods of Returned Products

Hendrik Lamsali
School of Technology Management & Logistics
College of Business (COB)
Universiti Utara Malaysia
Sintok, Malaysia
hendrik@uum.edu.my

***Abstract*—This paper studies the problem manufacturers facing to determine the collection methods for used product at the end of its life. Three collection methods that are practically applicable are studied namely pick-up, drop-off and mail return. This paper investigates the problem of assigning collection methods to collect returned products from customer zones that can maximize manufacturer's profit. A mixed integer non-linear programming model integrating the three collection methods is proposed to tackle the problem. The model is then tested using some problem instances and the results are promising. The potential and benefits of the proposed model are also highlighted.**

***Keywords*—reverse logistics, collection methods, mixed integer non-linear programming**

I. INTRODUCTION

Customers have several options of returning used products either via a drop-off facility, a mail return or a pick up collection method provided by the manufacturer. Several important factors that have been identified as influential in relations to customers' preferences over certain collection methods are monetary incentives (i.e; rebates, cash-backs and cash vouchers), proximity or availability of a nearby drop-off facility, and a 'free-of-charge' door-to-door pick-up collection. Factors such as environmental awareness, customer pressure and government's environmental regulations drive manufacturers' collection effort [1]. In this study, the objective is to investigate the problem of assigning the collection method to collect returned products from customers so as to maximize profit. Specifically, it is carried out to examine the potential incorporation of three collection methods of returned products in a single, profit maximization model. The remaining parts of this article are organized as follows: problem definition is presented in *Section II* then followed by survey of relevant literature in *Section III* and the model formulation in *Section IV*. *Section V* presents numerical examples and analysis of finding. Finally, *Section VI* summarizes conclusions of the research and also some further research directions.

II. PROBLEM DEFINITION

This study examines a manufacturer-typed product recovery network design. This type of collection network is practiced by many companies [2],[3]. Specific attention is given to the collection stage of product returns. At this stage, customers have several options of returning used products either via a drop-off facility, a mail delivery return or a pick up collection method provided by the manufacturer. It is up to the manufacturer to influence customers' preference and assign them to certain collection method using the incentive offers. As long as it is technically possible and economically viable, it is assumed that customers' decision to return their products as well as their preference over a particular collection method is heavily influenced by the amount of incentives offered. It is also assumed that customers have no other option to return their products.

In this study, the manufacturer is assumed to use its forward distribution networks to collect returned products. In particular, the manufacturer may select and appoint certain retailers as collection centres/drop-off points. Customers can also be clustered into certain zones instead of being considered as individuals to reduce complexity as shown by [4]. In terms of the return flow, only one collection centre can be chosen for the customers in each zone. Hence, the function of each collection centre will not be overlapping. Meanwhile, we assume that operating costs for every collection centres are the same and all facilities are homogenous as also depicted by [4]. The vehicles used are also assumed to be homogenous. The variable cost of a pickup trip is defined by the cost per unit of distance and the distance of travelled from the collection centre to the customer zone and back. The amount of incentives offered is assumed to affect customers' decision to return their products. The values of the incentives vary between the collection methods in order to compensate customers' effort and their travelling costs to return their products. It is also assumed that all collected products are recoverable and hence still have remaining values to be recaptured. In terms of customers' willingness to return their products, if the incentive offered is less than what the customers expect, then probability of customer return is zero. On the other hand, if the amount of incentive offered is equal or higher than the maximum amount of incentive that the customer expect for a particular product, then all customers will return their products. The amount of return will not change further if the amount of incentives increases above the maximum incentives that customers expect. In the mean time, the requirement by government regulations can be reflected in the form of minimum recovery rates. In this study, a manufacturer is assumed to be producing multiple products that can be returned by customers using either one of the three collection methods. Products such as ink cartridges, rechargeable batteries, disposable camera, mobile phones and books fit the bill.

III. SURVEY OF LITERATURE

The extended producer responsibility states that manufacturers are responsible for free taking back and recovery of their end-of-life products and must bear all or significant part of the collection and treatment costs [5],[6]. At the same time, the amount of collected returned products should at least satisfy the required minimum collection rate. It is also noted that collection of used products potentially accounts for a significant part of the total costs of any closed-loop supply chain [7]. Collection effectiveness depends on the consumers' willingness to return used products at the time of disposal [8]. It has been identified that two important factors which influence customers' willingness to return their products are accessibility and incentives [3],[6],[9]. Customers' convenience when returning their products should be maximized as it will eventually encourage more future returns [10]. In practice, the facilities need to be located within close proximity to the customers. Previous studies usually group customers based on geographical zones and each zone is served by one particular drop-off facility [4], [8] and [11]. In the mean time, incentives play a significant role in influencing customers' willingness to return their products. In [4], some manufacturers were able to influence the quantity of returns by using buy back campaigns and offering financial incentives to product holders. Apart from an increment in terms of product return quantities, the amount of incentives offered by the manufacturers influences the quality level of the returned products [4]. In the mean time, there is lack of research directly addressing the aforementioned collection methods of pick-up, drop-off and mail return. Notably, studies by [4],[8] and [11] investigated problems involving one of the above collection methods (except the mail return method in which was almost non-existence). Nonetheless, each collection method was studied separately (each manufacturer used only one collection method). In practice, this situation is not helping as manufacturer faces challenges to increase collection rates as well as potential profit. Hence, this research attempts to investigate the possibility of incorporating the three collection methods together in a single model in order to maximize collection rates and potential profit. The importance of the monetary incentives and how it affects manufacturer's profit and collection strategies when all collection methods are considered should also be investigated.

IV. MODEL FORMULATION

This research develops an integrated model for the manufacturer to decide the collection method for each customer zone and the amount of monetary incentives offered to customers for returning used products. The objective of the model is to find optimal assignment of collection methods to customer zones so as to maximize the total profit. The estimated amount of returned products of each type and quality classes available for return in each zone is assumed to be known. The model formulation of the drop-off collection method is based on the work of [4] and extensions have been made to incorporate other collection methods. For completeness, we introduce some parameters and decision variables that are used in the proposed model as follows:

Parameters

$I = \{1,..,n\}$: the set of returned product types;
$B = \{1,..,n_b\}$: the set of customer zones;
$Q = \{1,..,n_q\}$: the set of product quality classes;
$K = \{1,..,n_k\}$: the set of potential collection centres;
TA_i : Total amount of returned product type i;
T_{iqb}: Total amount of used product type i of quality q in customer's zone b;
CD_{bk} : Travelling cost per unit distance for drop off from customer zone b to collection centre k;
D_{bk} : Distance between potential collection centre k and customer zone b;
cv : Fixed cost of operating a vehicle;
CV : Pick up vehicle's travel cost per unit distance;
C_k : Fixed cost of operating a drop-off facility k;
CM_i : Cost of receiving and handling a unit of product i returned via mail;
CS_i : Customers' shipping/post cost to return a unit of product i via mail;
KV : Maximum load (capacity) of a vehicle;
KD_k : Maximum capacity of a collection centre k;
HP_{iq} :Maximum incentive of product i of quality q (pick up method);
HD_{iq} :Maximum incentive of product i of quality q (drop-off method);
HM_{iq} :Maximum incentive of product i of quality q (mail delivery method);
LP_{iq} : Minimum incentive of product i of quality q (pick up method);
LD_{iq} : Minimum incentive of product i of quality q (drop-off method);
LM_{iq} : Minimum incentive of product i of quality q (mail delivery method);
R_{iq} : Expected value per unit of product i in quality class q;
XR_i : Required minimum collection rate for product i;
W : A large number.

Decision variables

SP_{iq} : Incentive offered for product *i* of quality class *q* (pick up method);

SD_{iq} : Incentive offered for product *i* of quality class *q* (drop-off method);

SM_{iq} : Incentive offered for product *i* of quality class *q* (mail delivery method);

P_{iqb} : Proportion of product *i* of quality class *q* collected from customer zone *b;*

D_{iqb} : Proportion of product *i* of class *q* dropped off by customers in zone *b;*

M_{iqb} : Proportion of product *i* of quality class *q* returned from customer zone *b* ;

V_{bk} : Number of vehicles needed to collect and transport returned products from customer zone *b* to collection centre *k;*

Y_k : 1, if a drop-off facility (collection centre) is setup at site *k,* 0, otherwise;

XD_{bk} : 1, if product owners in zone *b* are assigned to drop-off their products at collection centre *k*, 0, otherwise;

XP_{bk} : 1, if product owners in zone *b* are assigned for pick up collection to collection centre *k*, 0, otherwise;

XM_{ib} : 1, if product owners of product *i* in zone *b* is assigned for mail delivery method, 0, otherwise;

α_{iqb} : 1, If product owners in zone *b* do not drop off their products, 0, otherwise;

δ_{iqb} : 1, If all product owners in zone *b* drop off their products, 0, otherwise;

β_{iqb} : 1, If product owners in zone *b* do not return their products (pick up), 0, otherwise;

ρ_{iqb} : 1, If all product owners in zone *b* return their products (pick up), 0, otherwise;

χ_{iqb} : 1, If product owners in zone *b* do not return their products (mail return delivery), 0, otherwise;

μ_{iqb} : 1, If all product owners in zone *b* return their products (mail return delivery, 0, otherwise.

Using the above notion the problem can be formulated as the following mixed integer non-linear programming model.

$$\text{Max} \quad Z_1 + Z_2 + Z_3$$

Where Z_1, Z_2 and Z_3 are profits from the pickup (not counting the operating costs of collection/drop-off centres), drop-off (counting all the operating cost of the collection/drop-off centres) and mail return methods respectively.

$$Z_1 = \sum_{i=1}^{n}\sum_{q=1}^{n_q}\sum_{b=1}^{n_b} T_{iqb}P_{iqb}(R_{iq} - SP_{iq}) - \sum_{b=1}^{n_b}\sum_{k=1}^{n_k}[cv + 2CVD_{bk}]V_{bk} \,,$$

$$Z_2 = \sum_{i=1}^{n}\sum_{q=1}^{n_q}\sum_{b=1}^{n_b} T_{iqb}D_{iqb}(R_{iq} - SD_{iq}) - \sum_{k=1}^{n_k} C_k Y_k \,,$$

$$Z_3 = \sum_{i=1}^{n}\sum_{q=1}^{n_q}\sum_{b=1}^{n_b} T_{iqb}M_{iqb}(R_{iq} - SM_{iq} - CM_i)$$

Subject to:

A collection centre, *k*, can receive collected products from more than one customer's zones, *b*, but each zone is assigned to only one collection method, and if it is assigned to pickup or drop-off method, it can only be assigned to one collection/drop-off centre as shown in (1):

$$\sum_{k=1}^{n_k} XP_{bk} + \sum_{k=1}^{n_k} XD_{bk} + XM_b = 1 \,, \quad b=1,\dots,n_b \qquad (1)$$

Returned products of all types and qualities collected via the pick-up and drop-off methods can only be delivered to a collection centre that is set up as follows :

$$XP_{bk} + XD_{bk} \le Y_k \,, \quad b=1,\dots,n_b,\ k=1,\dots,n_k \qquad (2)$$

The incentive values represent customers' willingness to return their products. In terms of the drop-off method, the relationships between the incentives and the proportion of products returned are as follows:

$$SD_{iq} \le (\sum_{k=1}^{n_k} CD_{bk}XD_{bk}) + LD_{iq} + W(1-\alpha_{iqb}) \,, \quad i=1,\dots,n,\ q=1,\dots,n_q,\ b=1,\dots,n_b \qquad (3)$$

$$SD_{iq} \ge (\sum_{k=1}^{n_k} CD_{bk}XD_{bk}) + LD_{iq} - W\alpha_{iqb} \,, \quad i=1,\dots,n,\ q=1,\dots,n_q,\ b=1,\dots,n_b \qquad (4)$$

$$SD_{iq} \le (\sum_{k=1}^{n_k} CD_{bk}XD_{bk}) + HD_{iq} + W\delta_{iqb} \,, \quad i=1,\dots,n,\ q=1,\dots,n_q,\ b=1,\dots,n_b \qquad (5)$$

$$SD_{iq} \ge (\sum_{k=1}^{n_k} CD_{bk}XD_{bk}) + HD_{iq} - W(1-\delta_{iqb}) \,, \quad i=1,\dots,n,\ q=1,\dots,n_q,\ b=1,\dots,n_b \qquad (6)$$

$$D_{iqb} \le 1 - \alpha_{iqb} \,, \quad i=1,\dots,n,\ q=1,\dots,n_q,\ b=1,\dots,n_b \qquad (7)$$

$$D_{iqb} \ge \delta_{iqb} \,, \quad i=1,\dots,n,\ q=1,\dots,n_q,\ b=1,\dots,n_b \qquad (8)$$

$$D_{iqb} \le [SD_{iq} - (\sum_{k=1}^{n_k} CD_{bk}XD_{bk}) - LD_{iq}]/[HD_{iq} - LD_{iq}] + W(\alpha_{iqb} + \delta_{iqb}), \quad i=1,\dots,n,\ q=1,\dots,n_q,\ b=1,\dots,n_b \qquad (9)$$

$$D_{iqb} \ge [SD_{iq} - (\sum_{k=1}^{n_k} CD_{bk}XD_{bk}) - LD_{iq}]/[HD_{iq} - LD_{iq}] - W(\alpha_{iqb} + \delta_{iqb}) \quad i=1,\dots,n,\ q=1,\dots,n_q,\ b=1,\dots,n_b \qquad (10)$$

As for the pick-up collection method, the relationships are given as follows:

$$SP_{iq} \le LP_{iq} + W(1-\beta_{iqb}) \,, \quad i=1,\dots,n,\ q=1,\dots,n_q,\ b=1,\dots,n_b \qquad (11)$$

$$SP_{iq} \ge LP_{iq} - W\beta_{iqb} \,, \quad i=1,\dots,n,\ q=1,\dots,n_q,\ b=1,\dots,n_b \qquad (12)$$

$$SP_{iq} \le HP_{iq} + W\rho_{iqb} \,, \quad i=1,\dots,n,\ q=1,\dots,n_q,\ b=1,\dots,n_b \qquad (13)$$

$SP_{iq} \geq HP_{iq} - W(1-\rho_{iqb})$, $i=1,\ldots,n$, $q=1,\ldots,n_q$, $b=1,\ldots,n_b$ (14)

$P_{iqb} \leq 1-\beta_{iqb}$, $i=1,\ldots,n$, $q=1,\ldots,n_q$, $b=1,\ldots,n_b$ (15)

$P_{iqb} \geq \rho_{iqb}$, $i=1,\ldots,n$, $q=1,\ldots,n_q$, $b=1,\ldots,n_b$ (16)

$P_{iqb} \leq [SP_{iq}-LP_{iq}]/[HP_{iq}-LP_{iq}]+W(\beta_{iqb}+\rho_{iqb})$, $i=1,\ldots,n$ $q=1,\ldots,n_q$, $b=1,\ldots,n_b$ (17)

$P_{iqb} \geq [SP_{iq}-LP_{iq}]/[HP_{iq}-LP_{iq}]-W(\beta_{iqb}+\rho_{iqb})$, $i=1,\ldots,n$, $q=1,\ldots,n_q$, $b=1,\ldots,n_b$ (18)

The relationships between the incentives and the proportion of products returned from zone *b* via mail are illustrated in the following equations:

$SM_{iq} \leq (CS_i XM_{ib}) + LM_{iq} + W(1-\chi_{iqb})$, $i=1,\ldots,n$, $q=1,\ldots,n_q$, $b=1,\ldots,n_b$ (19)

$SM_{iq} \geq (CS_i XM_{ib}) + LM_{iq} - W\chi_{iqb}$, $i=1,\ldots,n$, $q=1,\ldots,n_q$, $b=1,\ldots,n_b$ (20)

$SM_{iq} \leq (CS_i XM_{ib}) + HM_{iq} + W\mu_{iqb}$, $i=1,\ldots,n$, $q=1,\ldots,n_q$, $b=1,\ldots,n_b$ (21)

$SM_{iq} \geq (CS_i XM_{ib}) + HM_{iq} - W(1-\mu_{iqb})$, $i=1,\ldots,n$, $q=1,\ldots,n_q$, $b=1,\ldots,n_b$ (22)

$M_{iqb} \leq 1-\chi_{iqb}$, $i=1,\ldots,n$, $q=1,\ldots,n_q$, $b=1,\ldots,n_b$ (23)

$M_{iqb} \geq \mu_{iqb}$, $i=1,\ldots,n$, $q=1,\ldots,n_q$, $b=1,\ldots,n_b$ (24)

$M_{iqb} \leq [SM_{iq}-(CS_i XM_{ib})-LM_{iq}]/[HM_{iq}-LM_{iq}]+W(\chi_{iqb}+\mu_{iqb})$ $i=1,\ldots,n$, $q=1,\ldots,n_q$, $b=1,\ldots,n_b$ (25)

$M_{iqb} \geq [SM_{iq}-(CS_i XM_{ib})-LM_{iq}]/[HM_{iq}-LM_{iq}]-W(\chi_{iqb}+\mu_{iqb})$ $i=1,\ldots,n$, $q=1,\ldots,n_q$, $b=1,\ldots,n_b$ (26)

Note that constraints (9-10), (17-18) and (25-26) are active only when $\alpha_{iqb}=\delta_{iqb}=0, \beta_{iqb}=\rho_{iqb}=0, \chi_{iqb}=\mu_{iqb}=0$. No product can be returned using a collection method if the method is not chosen as shown in (27),(28) and (29):

$$D_{iqb} \leq \sum_{k=1}^{n_k} XD_{bk} , \quad i=1,\ldots,n ,\ q=1,\ldots,n_q ,\ b=1,\ldots,n_b \quad (27)$$

$$P_{iqb} \leq \sum_{k=1}^{n_k} XP_{bk} , \quad i=1,\ldots,n ,\ q=1,\ldots,n_q ,\ b=1,\ldots,n_b \quad (28)$$

$$M_{iqb} \leq XM_b , \quad i=1,\ldots,n ,\ q=1,\ldots,n_q ,\ b=1,\ldots,n_b \quad (29)$$

$$\sum_{i=1}^{n}\sum_{q=1}^{n_q}\sum_{b=1}^{n_b}(T_{iqb}D_{iqb}XD_{bk}+T_{iqb}P_{iqb}XP_{bk}) \leq KD_k , \quad k=1,\ldots,n_k \quad (30)$$

$$(\sum_{i=1}^{n}\sum_{q=1}^{n_q}T_{iqb}P_{iqb}XP_{bk})/KV = V_{bk} , \quad b=1,\ldots,n_b,\ k=1,\ldots,n_k \quad (31)$$

$$\sum_{q=1}^{n_q}\sum_{b=1}^{n_b}[T_{iqb}(P_{iqb}+D_{iqb}+M_{iqb})]/TA_i \geq XR_i , \quad i=1,\ldots,n \quad (32)$$

$V_{bk} \geq 0$ and integer, $b=1,\ldots,n_b$, $k=1,\ldots,n_k$ (33)

$P_{iqb}, D_{iqb}, M_{iqb}, SP_{iq}, SD_{iq}, SM_{iq} \geq 0$ and $P_{iqb}, D_{iqb}, M_{iqb} \leq 1$ $i=1,\ldots,n$, $q=1,\ldots,n_q$, $b=1,\ldots,n_b$ (34)

$Y_k, XP_{bk}, XD_{bk}, XM_{ib}, \alpha_{iqb}, \delta_{iqb}, \beta_{iqb}, \rho_{iqb}, \chi_{iqb}, \mu_{iqb} \in \{0,1\}$, $i=1,\ldots,n$, $q=1,\ldots,n_q$, $b=1,\ldots,n_b$ $k=1,\ldots,n_k$ (35)

V. PROBLEM INSTANCES AND ANALYSIS OF FINDING

The performance of the proposed model is evaluated using nine problem instances. The proposed model was written in C++ and solved using LINGO (version 10). The experiments were conducted on a PC with Intel Core 2 processor, 2.13GHz and 2 GB RAM. All data were randomly generated within the following intervals: TA_i = [3300,5100]; T_{iqb} = [200,800]; CD_{bk} = [0.5,20.0]; XR_i = [0.50,0.90]; R_{iq} = [20.0,60.0]; $LP_{iq}/LD_{iq}/LM_{iq}$ = [2.0,8.0]; $HP_{iq}/HD_{iq}/HM_{iq}$ = [8.0,15.0]; KD_k = [3600,6500]; CM_i = [4.0,5.0]; CS_i = [8.0,11.0]. The similarities are in terms of n, n_q, n_b and n_k (n=2; n_q=2; n_b=4; n_k=2). The following table illustrates the tests' outcomes:

TABLE 1. RESULTS FROM THE PROBLEM INSTANCES

Problem Instances	Objective Function values ($)	Computation Times (in seconds)	Assigned Collection Methods
1	74,880,000.00	14,459.00	Mail return method*
2	88,636.90	2056.00	
3	29,873.96	409.73	
4	145,897.00	2950.00	
5	109,139.00	5881.00	
6	124,631.10	1608.36	
7	114,797.00	21.67	
8	116,911.30	17.63	
9	99,171.80	758.00	

**Other collection methods were not selected*

The results show that some instances were solved in fairly minimal computational times, while others require more time to solve. The performance of the proposed model is promising but more test using larger problem instances is needed. The results also depicted that mail return delivery has been selected as the collection method for all customer zones. This assignment also means that other important constraints such as capacity of collection centres and vehicles can be excluded from managerial considerations. The complication of having to deal with factors such as transportation cost, handling of collection centres, incentives schemes to offset customers' travelling cost, and transport arrangement between collection centres and reprocessing facility could also be avoided by opting for mail collection. However, it is also worth noting that mail return delivery is only practical for small item. Hence, bulky items such as refrigerator, washing machine and television are almost infeasible to be returned using mail delivery unless customers are compensated with higher monetary incentives that bear the necessary shipping cost as well as the sales price.

VI. CONCLUSION

This study presented analysis on product return channels (initial collection methods) namely drop-off, pick-up and mail return delivery. A Mixed integer non-linear programming model is put forward to tackle the problem in order to find optimal allocation of the collection methods. The proposed model was then tested using some problem instances to demonstrate its potential and usability. The result shows that the model is promising and beneficial particularly for organizations that are capable of providing all three collection methods. Having a possibility of offering all collection methods to the customers also means higher probability of getting better product return rates as well as potential profit. Nevertheless, the results also pointed out that mail return method has been chosen as the collection method for all problem instances. This scenario indicated the need to further examine the model using more and larger problem instances. Nonetheless, this solution is only viable for small items. In other words, changes on the incentives amount should be considered if a firm is dealing with the recovery of a mid-to-bulky size of returned items. Another possibility is to allow other collection methods such as drop-off or pick-up to enter into the solution.

In all, it can be concluded that the proposed model has achieved its intended goal. Nonetheless, it is also important to examine the practicality of the proposed model using larger instances. Further investigation using heuristic methods is also needed since the problem is classified as NP-hard [4].

REFERENCES

[1] Baenas, JMHojas, De Castro, R, Battistelle, RAG, and Junior, JAG, "A study of reverse logistics flow management in vehicle battery industries in the midwest of the state of Sao Paulo", *Journal of Cleaner Production*, Vol. 19, no. 2-3, pp. 168-172, 2011.

[2] Savaskan R.C., and van Wassenhove L.N., "Reverse channel design: The case of competing retailers", *Management Science*, vol.52, pp.1-14, 2006.

[3] Zaarour N., Melachrinoudis E., and Min H., "Developing the reverse logistics network for product returns", *Proceeding in SPIE*, vol.6385, 2006.

[4] Aras N. and Aksen D., "Locating collection centers for distance-and-incentive-dependent returns", *International Journal of Production Economics*, vol.111, pp.316-333, 2008.

[5] Mansour A. and Zarei M., "A multi-period reverse logistics optimization model for end-of-life vehicles recovery based on EU Directive", *International Journal of Computer Integrated Manufacturing*, vol.21, pp.764-777, 2008.

[6] Shulman, JD., Coughlan, AT., and Savaskan, RC., "Optimal Reverse Channel Structure for Consumer Product Returns", *Marketing Science*, Vol. 29, No. 6, pp. 1071–1085, 2010.

[7] Dekker R, Fleischmann M., Inderfurth K., and Van Wassenhove L.N., *Reverse logistics network design: Quantitative models for closed-loop supply chains*, Berlin: Springer, 2004.

[8] Wojanowski R., Verter V., and Boyaci T., "Retail-collection network design under deposit-refund", *Computers & Operations Research*, vol.34, pp.324-345, 2007.

[9] Ilgin, M.A., and Gupta, S.M., "Environmentally conscious manufacturing and product recovery (ECMPRO): A review of the state of the art", *Journal of Environmental Management*, Vol.91, pp.563-591, 2010.

[10] Min H., and Ko H-J., "The dynamic design of a reverse logistics network from the perspective of third-party logistics service providers", *International Journal of Production Economics*, vol.113, pp.176-192, 2008.

[11] Aras N, Aksen D., and Tanugur, A.G., "Locating collection centers for incentive-dependent returns under a pick up policy with capacitated vehicles", *European Journal of Operational Research*, vol.191, pp.1223-1240, 2008.