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WASTE MANAGEMENT IN REVERSE SUPPLY CHAIN CONSIDERING PRICING

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ABSTRACT

Reverse supply chain problem is one of the concepts in supply chain which as well explore wastes management in relation to customer. In reverse supply chains, wastes are recovered and reproduced leading to profit making of new products which is produced. In this study, residuals, after transferring by costumer, send to production station, sorting station and different manufacturing processes (melting, forging, clamping, painting ...) for reproduction. After completion several production processes, diverse products resend to costumers. Here, considering different cost factors and also pricing concept and reproduced parts, the mathematical model of optimizing manufacturing cost is developed. The solution is a useful tool in strategic decision making for municipalities.

Keywords: Reverse supply chain, Waste management, Pricing, Mathematical optimization.

1. INTRODUCTION

An effective supply chain is a competitive advantage for firms helping them to be capable with environmental turbulences. A supply chain is a network of supplier, production, distribution centers and channels between them configured to acquire raw materials, convert them to finished products, and distribute final products to customers. Supply chain network design is one of the most important strategic decisions in supply chain management. In general, network structure decisions contain setting the numbers, locations and capacities of facilities and the quantity of flow between them Amiri [1].

Recently, many companies such as Kodak, Xerox and HP have concentrated on remanufacturing processes and obtained significant achievements in this area [2]. Meade, et al. [3] classify driving forces led to increased interest and investment in reverse supply chain into two groups: environmental factors and business factors. The first group explores environmental impacts of used products, environmental legislations and growing environmental consciousness of

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customers. The design and establishment of the supply chain network is a very important decision to be effective for several years, during which the parameters of the business environment (e.g. demand of customers) may change [4].

In the Korea, the extended product responsibility is in force system from 2003 that the obligation is given as a producer as it recycles more than a constant amount of the waste that can be recycled [5-7]. Reverse logistics is defined by the European working group (REVLOG) as "the propose of planning, implementing and controlling flows of raw materials, in process inventory, and finished goods, from the point of use back to point recovery or point of proper disposal". In a broader sense, reverse logistics refers to the distribution activities involved in product returns, source reduction, conservation, recycling, substitution, reuse, disposal, refurbishment, repair and remanufacturing (Stock) [8]. Concerning reverse logistics, many works have been studied in different areas and operations included such as reuse, recycling, remanufacturing logistics etc. In reuse logistics models, Kroon and Vrijens [9] conducted a case study focusing the design of a logistics system for reusable transportation packages.The authors developed an mIP (mixed integer programming), closely related to a classical un-capacitated warehouse location model. In recycling models, Barros, et al. [10] developed a mixed integer program model by considering two-echelon location problems with capacity constraints based on a multi-level capacitated warehouse location problem. Pati, et al. [11], developed a mdel based on a mixed integer goal programming model (mIGP) to solve the problem. The model studied the inter-relationship between multiple objectives of a recycled paper distribution network. In remanufacturing models, Kim, et al. [12] discussed a notion of remanufacturing systems in reverse logistics environment. Jayaraman, et al. [13] presented a mixed integer program to determine the optimal number and locations of remanufacturing facilities for the electronic equipment. Lee, et al. [14] proposed the reverse logistics network problem (rLNP) minimizing total reverse logistics various shipping costs. This research offers an efficient MILP model for multi-stage reverse logistics network design that could support recovery and disposal activities. This research is organized as follows. In the next section, the related literature is reviewed. The model notations and mathematical model for remanufacturing system are proposed in Section 3. Section 4 provides an analysis of the model using an illustrative example and some insights into the proposed model and finally, concluding remarks and some possible future works are given in Section 5.

2. LITERATURE REVIEW

While the body of literature for reverse supply chain network design implied, mixed-integer programming (MIP) models were the models used commonly. These models include simple incapacitated facility location models to complex capacitated multi-stage or multi-commodity models. The usual objective of the models was to determine the least cost system design, that is usually involves making tradeoffs among fixed opening costs of facilities and transportation costs. Melo, et al. [15] and Klibi, et al. [16] presented comprehensive reviews on supply chain network design problems to support variety of future research directions.

2.1. Reverse Supply Chain Network

Fleischmann, et al. [17] presented a comprehensive review on the application of mathematical modeling in reverse logistics management. As one of the focal works in reverse supply chain network design, Barros, et al. [10] proposed a MILP model for a sand recycling network. A heuristic algorithm is also used to solve the problem. Jayaraman, et al. [13] developed a MILP model for reverse logistics network design under a pull system based on customer demands for recovered products. The objective of the proposed model was to minimize the total costs. Also, Krikke, et al. [18] designed a MILP model for a two-stage reverse supply chain network for a copier manufacturer. In this model, both the processing costs of returned products and inventory costs were considered in the objective function to minimize the total cost. Jayaraman, et al. [19] extended their prior work to solve the single product two-level hierarchical location problem involving the reverse supply chain operations of hazardous products. They also developed a heuristic to handle relatively large-sized problems. Min, et al. [20] proposed a mixed-integer nonlinear programming (MINLP) model and a genetic algorithm that could solve a multi-period reverse logistics network design problem involving both spatial and temporal consolidation of returned products. Aras, et al. [21] developed a MINLP model for determining the locations of collection centers in a simple reverse supply chain network. The important point about this work was the capability of presented model for determining the optimal buying price of used products with the objective of maximizing profit. They developed a heuristic based on tabu search to solve the model. Pati, et al. [11] proposed a mixed-integer goal programming (MIGP) for paper recycling logistics network. The considered goals included: (1) minimizing the positive deviation from the planned budget allocated for reverse logistics activities, (2) minimizing the positive deviation from the maximum limit of non-relevant wastepaper and (3) minimizing the negative deviation from the minimum desired waste collection.

Demand uncertainty and uncertainty in the type and quantity of returned products are the important elements being considered in the design of reverse and closed-loop supply chain networks. According to this fact, Listes and Dekker [22] proposed a stochastic mixed-integer programming (SMIP) model for a sand recycling network design to maximize the total profit. This research was an extension of the work done by Barros, et al. [10]. Lieckens and Vandaele [7] combined the traditional MILP models with queuing models to cope with high degree of uncertainty and some dynamic aspects in a reverse logistics network design problem. Since this extension introduced nonlinear relationships, the problem was defined as a MINLP model. A genetic algorithm was developed to solve the proposed model.

2.2. Framework for Remanufacturing

Various types of remanufacturing systems exists based on the working industry. In most industries, for example, computer, mobile phone, copy machine, and automotive industry, the remanufacturing process varies from each other in terms of specific ‘process’ itself. However, there also exist common types of remanufacturing processes being categorized as process characteristics such as collection, disassembly, refurbishment, and assembly. In this sense, the following remanufacturing system is considered without loss of generality. Remanufacturing system begins with returned products including end-of-life product from customers. Then, they are collected to the collection centers. Since a product includes of several parts, the returned products are disassembled to remanufacturing and the rests, beyond the remanufacturing capacity, are sent to the remanufacturing subcontractor centers. The furnished products from the collection site are disassembled in the disassembly site. Disassembled parts are classified into the reusable parts and non-reusable parts. Finally parts in inventory are supplied to the manufacturing shops according to the company's own production plan. For example, in a mobile phone industry, manufacturers collect and test the used phones. If they are working, they go the secondary market for rental or resale. Otherwise, they go into the remanufacturing system to reuse parts or segments, i.e. PCB, display, speaker, and microphone. Defective phones are going to disassembly, cleaning, and reassembly with new parts or modules if necessary [23].

De Brito, et al. [24] discussed network structures and report cases pertaining to the design of remanufacturing networks by the original equipment manufacturers or independent manufacturers, the location of remanufacturing facilities for copiers, especially Canon copiers and other equipment and the location of IBM facilities for remanufacturing in Europe. They also presented case studies on inventory management for remanufacturing networks of engine and automotive parts for Volkswagen and on Air Force depot buffers for disassembly, remanufacturing and reassembly. Finally, they presented case studies on the planning and control of reverse logistics activities, and in particular inventory management cases for remanufacturing at a Pratt & Whitney aircraft facility, yielding decisions of lot sizing and scheduling.

Bostel, et al. [25] proposed a review of problems and models based on the hierarchical planning horizon and degree of correlation between forward and reverse flows. Strategic planning models are focused on network design problems, while tactical and operational models address a number of specific problems. In this context they discussed a number of inventory management models with reverse flows, including periodic and continuous review deterministic and stochastic inventory models. The special issue published by Verter and Boyaci [26] contains three papers on optimization models for facility location and capacity planning for remanufacturing and a paper on assessing the benefits of remanufacturing options. Guide and Van Wassenhove [27] discuss assumptions of models for reverse supply chain activities, and in particular operational issues for remanufacturing and remanufactured product market development. Several papers deal with optimal policies for remanufacturing activities, pertaining to acquisition, pricing, order quantities, lot sizing for products over a finite life cycle. In recent years there has been considerable interest in inventory control for joint manufacturing and remanufacturing systems in forward–reverse logistics networks. As mentioned by El-Sayed, et al. [28], a forward–reverse logistic network establishes a relationship between the market that releases used products and the market for new products. When the two markets coincide, and the manufacturing and remanufacturing activities are strongly connected, the system is called a closed-loop network; otherwise it is called an open-loop network Salema, et al. [29]. Dobos [30] found optimal inventory policies in a reverse logistics system with special structure while assuming that the demand is a known function in a given planning horizon and the return rate of used items is a given function. Dobos [30] minimized the sum of the holding costs in the stores and costs of the manufacturing, remanufacturing and disposal. The necessary and sufficient conditions for optimality were derived from the application of the maximum principle of Pontryagin Seierstad and Sydsaeter [31]. Their results were constrained to deterministic demand and return process with no consideration on the dynamics of production facilities. Taking a closer look at the dynamic characteristic of the production planning problems, one can notice that the stochastic optimal control theory, such as in Akella and Kumar [32], Dehayem, et al. [33], Hajji, et al. [23] and references therein, is not yet used in reverse logistics.

Kibum, et al. [34] discussed the remanufacturing process of reusable parts in reverse logistics, where the manufacturing has two alternatives for supplying parts: either ordering the required parts to external suppliers, or overhauling returned products and bringing them back to "as new" condition. The study presented in Chung, et al. [35] analyzed a close-loop supply chain inventory system by examining used products returned to a reconditioning facility where they are stored, remanufactured, and then shipped back to retailers for retail sale. The findings of the study presented in Chung, et al. [35] demonstrated that the proposed integrated centralized decision-making approach can substantially improve efficiency. The majority of the previous works are based on mathematical programming. An example of such models can be found in El-Sayed, et al. [28] where a multi-period multi echelon forward–reverse logistics network model is developed. The control of the manufacturing and remanufacturing production facilities, based on their time dynamics is very limited in the literature.

3. PROBLEM DEFINITION AND FORMULATION

The reverse logistics network discussed in this research is a multi-stage logistics network including customer, collection, disassembly, refurbish and disposal centers.

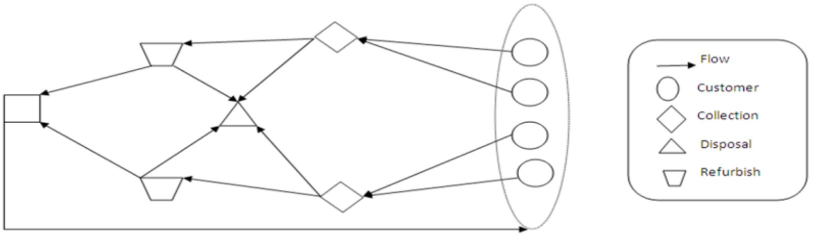

Fig.1. Structure of reverse supply chain network

As illustrated in Fig. 1, in the reverse flow, returned products are collected in collection centers and after inspecting the recoverable products are shipped to disassembly facilities, and scrapped products are shipped to disposal centers. With this strategy, excessive transportation of returned products (especially scrapped products) is prevented and the returned products can be shipped directly to the appropriate facilities. The disassembled parts from products in disassembly facilities are shipped to refurbish and disposal centers through a push system. After the refurbish process, the refurbished parts are delivered to customers as new parts. A predefined percentage of demand of each customer zone is assumed to result in return products and a predefined value is determined as an average disposal rate. The average disposal rate is associated with the quality of returned products; because high quality returns have a capability for recovery process (remanufacturing and de-manufacturing) and low quality returns should be entered to a safe disposal process.

Under the above situations, the remanufacturing company is interested in minimizing total remanufacturing cost so that eventually it can maximize total profit. To achieve the goal, while meeting part demands from manufacturing centers, the company determine how many returned products should be thrown into the remanufacturing process such as refurbishing and disassembling for 'as new' condition. The other issues to be addressed by this study are to choose the location and determine the number of collection, disassemble, refurbish and disposal centers and to determine the quantity of flow between network facilities. The following notation is used in the formulation of proposed model.

Indices:

i Index of collection/inspection center $i = 1,\ldots, I$

j Index of disassembly center $j = 1,\ldots, J$

k Index of refurbish center $k = 1,\ldots,K$

m Index of disposal center $m = 1,\ldots,M$

n Index of customer $n = 1,\ldots,N$

p Index of product $p= 1,\ldots,P$

l Index of part $l= 1,\ldots,L$

Parameters:

d_{np} Demand of customer n for refurbished products p

r_{np} Returns of used products p from customer n

s_l Average disposal fraction part l

re_{ijp} Exit of returned product p from collection center i to disassemble center j

cc_{ip} Capacity of handling returned products p at collection/inspection i

cs_{jp} Capacity of handling recoverable products p at disassembly center j

cr_{kl} Capacity of handling refurbished parts k at refurbish center k

cd_{ml} Capacity of handling scrapped parts l at disposal center m

π_{lp} The number of disassembled parts l from products p

a_{ip} set-up cost of collection/inspection center i for returned product p

b_{jp} set-up cost of disassembly center j for recoverable product p

c_{kl} set-up cost of refurbish center k for part l

o_{ml} set-up cost of disposal center m for part l

e_{nip} Shipping cost per unit of returned products p from customer n to collection/inspection center i

q_{ijp} Shipping cost per unit of recoverable products p from collection / inspection center i to disassembly center j

t_{jkl} Shipping cost per unit of parts l from disassembly center j to refurbish center k
v_{jml} Shipping cost per unit of parts l from disassembly center j to disposal center m
α_{ip} The idle cost of collection/inspection center i for product p
β_{jp} The idle cost of disassembly center j for product p
γ_{kl} The idle cost of refurbish center k for part l
λ_{ml} The idle cost of disposal center m for part l
ci_{ip} The inspection cost of returned products p in collection/inspection center i
ca_{jp} The disassembly cost of recoverable products p in disassembly center j
cp_{kl} The refurbish cost of disassembled parts l in refurbish center k
ch_{ml} The disposal cost of disassembled parts l in disposal center m

Decision variables:

QE_{nip} Quantity of returned products p shipped from customer n to collection/inspection center i
QQ_{ijp} Quantity of recoverable products p shipped from collection/inspection center i to disassembly center j

QT_{jkl} Quantity of parts l shipped from disassembly center j to refurbish center k
QV_{jml} Quantity of parts l shipped from disassembly center j to disposal center m

$$X_{ip} = \begin{cases} 1 & \text{if a collection center i is set} - \text{uped} \\ 0 & \text{otherwise} \end{cases} \qquad \forall\, i, p$$

$$Y_{jp} = \begin{cases} 1 & \text{if a disassembly center j is set} - \text{uped} \\ 0 & \text{otherwise} \end{cases} \qquad \forall\, j, p$$

$$G_{kl} = \begin{cases} 1 & \text{if a refurbish center k is set} - \text{uped} \\ 0 & \text{otherwise} \end{cases} \qquad \forall\, k, l$$

$$\delta_{ml} = \begin{cases} 1 & \text{if a disposal center m is set} - \text{uped} \\ 0 & \text{otherwise} \end{cases} \qquad \forall\, m, l$$

Using above indices and parameters, the mathematical formulation for this problem can be stated as follows.

$$\min Z = \left\{ \sum_{i=1}^{I} \sum_{p=1}^{P} (a_{ip} * X_{ip}) + \sum_{j=1}^{J} \sum_{p=1}^{P} (b_{jp} * Y_{jp}) + \sum_{k=1}^{K} \sum_{l=1}^{L} (c_{kl} * G_{kl}) + \sum_{m=1}^{M} \sum_{l=1}^{L} (o_{ml} * \delta_{ml}) \right.$$

$$+ \sum_{n=1}^{N} \sum_{i=1}^{I} \sum_{p=1}^{P} (ci_{\mathrm{ip}} + e_{nip}) * \left(QE_{nip}\right) + \sum_{\mathrm{i}=1}^{\mathrm{I}} \sum_{\mathrm{j}=1}^{\mathrm{J}} \sum_{\mathrm{p}=1}^{\mathrm{P}} (ca_{\mathrm{jp}} + q_{ijp}) * \left(QQ_{\mathrm{ijp}}\right)$$

$$+ \sum_{\mathrm{j}=1}^{\mathrm{J}} \sum_{\mathrm{k}=1}^{\mathrm{K}} \sum_{\mathrm{l}=1}^{\mathrm{L}} \left(cp_{kl} + t_{jkl}\right) * (QT_{\mathrm{jkl}}) + \sum_{\mathrm{j}=1}^{\mathrm{J}} \sum_{\mathrm{m}=1}^{\mathrm{M}} \sum_{\mathrm{l}=1}^{\mathrm{L}} (ch_{\mathrm{ml}} + v_{\mathrm{jml}}) * \left(QV_{\mathrm{jml}}\right)$$

$$+ \sum_{i=1}^{I} \sum_{p=1}^{P} \alpha_{ip} * (X_{ip} * cc_{\mathrm{ip}} - \sum_{\mathrm{n}=1}^{\mathrm{N}} QE_{nip}) + \sum_{\mathrm{j}=1}^{\mathrm{J}} \sum_{\mathrm{p}=1}^{\mathrm{P}} \beta_{jp} * (Y_{jp} * cs_{\mathrm{jp}} - \sum_{\mathrm{i}=1}^{\mathrm{I}} QQ_{\mathrm{ijp}})$$

$$+ \sum_{\mathrm{k}=1}^{\mathrm{K}} \sum_{\mathrm{l}=1}^{\mathrm{L}} \gamma_{\mathrm{kl}} * (G_{kl} * cr_{\mathrm{kl}} - \sum_{\mathrm{j}=1}^{\mathrm{J}} QT_{\mathrm{jkl}}) + \sum_{\mathrm{m}=1}^{\mathrm{M}} \sum_{\mathrm{l}=1}^{\mathrm{L}} \lambda_{ml} * (\delta_{ml} * cd_{\mathrm{ml}}$$

$$- \sum_{\mathrm{j}=1}^{\mathrm{J}} QV_{\mathrm{jml}}) \qquad (1)$$

subject to:

$$\sum_{i=1}^{I} QE_{nip} \geq r_{\mathrm{np}} * d_{\mathrm{np}} \qquad \forall p \in P, n \in \mathrm{N} \qquad (2)$$

$$re_{\mathrm{ijp}} * \sum_{n=1}^{N} QE_{nip} = \sum_{\mathrm{j}=1}^{\mathrm{J}} QQ_{\mathrm{ijp}} \qquad \forall \mathrm{i} \in \mathrm{I}, p \in \mathrm{P} \qquad (3)$$

$$QT_{\mathrm{jkl}} = (1 - s_{\mathrm{l}}) \sum_{p=1}^{P} \sum_{i=1}^{I} \pi_{\mathrm{lp}} * QQ_{\mathrm{ijp}} \qquad \forall l \in L, k \in K, j \in J \qquad (4)$$

$$QV_{\mathrm{jml}} = s_{\mathrm{l}} \sum_{p=1}^{P} \sum_{i=1}^{I} \pi_{\mathrm{lp}} * QQ_{\mathrm{ijp}} \qquad \forall l \in L, m \in M, j \in J \qquad (5)$$

$$\sum_{n=1}^{N} QE_{nip} \leq cc_{\mathrm{ip}} * X_{ip} \qquad \forall \mathrm{i} \in \mathrm{I}, \mathrm{p} \in \mathrm{P} \qquad (6)$$

$$\sum_{i=1}^{I} QQ_{\mathrm{ijp}} \leq cs_{\mathrm{jp}} * Y_{jp} \qquad \forall j \in J, p \in P \qquad (7)$$

$$\sum_{j=1}^{J} QT_{\mathrm{jkl}} \leq cr_{\mathrm{kl}} * G_{kl} \qquad \forall k \in K, l \in L \qquad (8)$$

$$\sum_{j=1}^{J} QV_{\text{jml}} \leq cd_{\text{ml}} * \delta_{ml} \qquad \forall m \in M, l \in L \qquad (9)$$

$$QE_{nip}, QQ_{\text{ijp}}, QT_{\text{jkl}}, QV_{\text{jml}}, \geq 0 \qquad (10)$$

$$X_{ip} \in \{0,1\} \qquad (11)$$

$$Y_{jp} \in \{0,1\} \qquad (12)$$

$$G_{kl} \in \{0,1\} \qquad (13)$$

$$\delta_{ml} \in \{0,1\} \qquad (14)$$

Objective function (1) minimizes the total cost, which includes set-up costs, transportation costs, operation costs and idle costs of facilities. This means that our model tries to minimize both the costs from remanufacturing process and the utilization of remanufacturing facilities at the same time. Constraint (2) ensures that the demands of all customers are satisfied and returned products from all customers are collected. Constraint (3) represents the balance equation for the products that are entered to disassembly center and are exited from collection center. Constraints (4)-(5) assure the flow balance at disassembly, refurbish and disposal centers. Equations (6)-(9) are capacity constraints on facilities. Constraint (10) checks for the non-negativity of decision variables and the last four Constraints check for binary variables.

4. AN ILLUSTRATIVE EXAMPLE AND INSIGHT INTO THE MODEL

Using a numerical example, the applicability of the model in the proposed framework is illustrated and some insights into the proposed model is gained. A small set of stochastic data is prepared. It is assumed that there are three types of products and five types of parts from those products, too three collection/inspection sites, five disassembly sites, four refurbish sites, three disposal sites and five customers. Rate of return of used products p from customer n, rate of Exit returned product p from collection center i to disassemble center j and Average disposal fraction parts be considered 0.3, 0.8 and 0.5, respectively. The capacity of collection/inspection and disassembly sites is set to be in range of [500, 1000] units of product and the capacity refurbish and disposal sites in range of [5000, 10000] units of part. The set-up cost of the facilities is set to be in range of [100, 200] dollars, transportation cost of products and parts between facilities are set to be in range of [1, 10] dollars, idle cost of the facilities are set to be in range of [1, 20] dollars and operation costs are set to be in range of [5, 20] dollars. The LINGO 9.0 software is used for solving our mixed-integer programming model on a PC.

Table-1. Demand of customer n for refurbished products p

d_{np}			
n \ p	1	2	3
1	100	140	100
2	160	100	200
3	700	90	160
4	90	170	200
5	130	140	130

Table-2. The number of disassembled parts l from products p

π_{lp}			
l \ p	1	2	3
1	16	10	13
2	12	14	12
3	8	13	19
4	11	6	19
5	5	14	5

Table-3. Shipping cost per unit of returned products p from customer n to collection/inspection center i

e_{nip}									
p	1			2			3		
n \ i	1	2	3	1	2	3	1	2	3
1	9	3	4	2	4	6	9	8	8
2	8	10	7	4	7	6	6	2	10
3	9	5	3	8	9	8	2	9	6
4	7	9	6	4	10	6	2	5	5
5	5	10	7	3	5	4	4	2	4

The results are shown in Tables 4–11. Table 4 shows the number of collected products from customers at collection/inspection site. Table 5 shows the number of recoverable products at disassembly site. Table 6 shows the number of refurbished parts at refurbished site. Table 7 shows the number of scrapped parts at disposal site. $X_{ip}, Y_{jp}, G_{kl}, \delta_{ml}$ Decision variables are determined the number of optimal quantity sites.

Table-4. Quantity of returned products p shipped from customer n to collection/inspection center i

QE_{nip}									
p	1			2			3		
n \ i	1	2	3	1	2	3	1	2	3
1	0	0	30	0	0	42	0	30	0
2	0	0	48	0	0	30	0	60	0
3	0	0	211	0	0	27	0	48	0
4	0	0	27	0	0	51	0	60	0
5	0	0	39	0	0	45	0	42	0

Table-5. Quantity of recoverable products p shipped from collection/inspection center i to disassembly center j

QQ_{ijp}															
P	1					2					3				
i \ j	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	192	0	0
3	0	0	284	0	0	0	0	156	0	0	0	0	0	0	0

Table-6. Quantity of parts l shipped from disassembly center j to refurbish center k

QT_{jkl}																				
l	**1**				**2**				**3**				**4**				**5**			
j \ **k**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	4300	4300	4300	4300	3948	3948	3948	3948	3974	3974	3974	3974	3854	3854	3854	3854	2282	2282	2282	2282
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table-7. Quantity of parts l shipped from disassembly center j to disposal center m

QV_{jml}															
l	**1**			**2**			**3**			**4**			**5**		
j \ **M**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	4300	4300	4300	3948	3948	3948	3974	3974	3974	3854	3854	3854	2282	2282	2282
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table-8. The number of collection/inspection sites

X_{lp}			
l \ **p**	**1**	**2**	**3**
1	0	0	0
2	0	0	1
3	1	1	0

Table-9. The number of disassembly sites

Y_{jp}			
j \ **p**	**1**	**2**	**3**
1	0	0	0
2	0	0	0
3	1	1	1
4	0	0	0
5	0	0	0

Table-10. The number of refurbish sites

G_{kl}					
k \ **l**	**1**	**2**	**3**	**4**	**5**
1	1	1	1	1	1
2	1	1	1	1	1
3	1	1	1	1	1
4	1	1	1	1	1

Table-11. The number of disposal sites

m \ l (δ_{ml})	1	2	3	4	5
1	1	1	1	1	1
2	1	1	1	1	1
3	1	1	1	1	1

4.1. Pricing

The purpose of this study is to minimization of the costs to maximize of the profit. However, the organization's profit for refurbishing parts is increased in a way to consider different factors of cost and various techniques of pricing. First the total costs of refurbishing each of parts according to represented function in mathematical model are computed, and then the costs of each parts are got, using an equation. The equation considers a 20% profit over head.

$1.2(price_l * \text{quantity}_l) = \text{total cost}_l$

$price_l$:the price of each of part l

quantity_l:the total quantities of each of refurbished parts l

total cost_l: the total costs of refurbishing each of parts l

total cost_l=634724

quantity_1 =12900

$1.2(price_l * 12900) = 634724$

$price_l$=41

total cost_2=462211

quantity_2 =15792

$1.2(price_2 * 15792) = 462211$

$price_2$=24

total cost_3=348543

quantity_3 =15896

$1.2(price_3 * 15896) = 348543$

$price_3$=18

total cost_4=408435

quantity_4 =11562

$1.2(price_4 * 11562) = 408435$

$price_4$=29

total cost_5=326016

quantity_5 =6846

$1.2(price_5 * 6846) = 326016$

$price_5$=40

5. CONCLUSIONS

In this research, reverse logistics network problem is addressed for treating a remanufacturing problem which is one of the most important problems in the environment situation for the recovery of used products and materials. Based on this system, a general framework was proposed in view of supply planning and developed a mathematical model to optimize the supply planning function. The model determines the quantity of products/parts processed in the remanufacturing facilities while minimizing the total remanufacturing cost. A numerical example was illustrated to analyze and validate the model by using a small set of stochastic data. Our research results can be guidelines on the relevant research. The proposed remanufacturing framework and model can be a useful tool to the various industries after customizing for specific industries. However, as the proposed model is introduced as a general framework, many future works can be conducted. Above all, the proposed framework with remanufacturing can be effectively enhanced by adopting more industry practices and so the mathematical model does. Since the proposed model is formulated as mixed-integer programming, the computational burden for optimal solution increases exponentially as the size of problem rises. Thus, an efficient heuristic algorithm needs to be developed in order to solve the large-scale problems. Many possible future research directions can be defined in the area of logistics network design under uncertainty. Time complexity is not addressed in this research, however, since the computational time increases significantly when the size of problem and the number of scenarios increase, therefore developing efficient exact or heuristic solution methods is also a critical need in this area.

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