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FACILITY LOCATION MODEL FOR REVERSE LOGISTICS

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Abstract:
This paper presents a study that characterizes, formulates, and solves the reverse logistic network design. A Mixed Linear Program model is formulated that systematically minimizes reverse logistics operating costs for the strategic problem facility location of collection sites, cannibalization and recycling. The facility location is a central issue of the logistics networks. In this paper we are interested in optimizing of the sites facility location for product end of life reverse logistics network. This model allows determining to open or to close the sites previously in the reverse logistics network. The decisions mentioned above are taken to minimize the cost of products recovery at the end of life. We wish to solve the problem of site facility location site in a reverse logistics network for various times of time considered in strategic planning. The inclusion of such an element means to solve a multi-time step problem: decisions taken at a given time are related to those taken in previous times and take account of future needs. To solve the mathematical program, we have used the evaluation and separation process implemented in CPLEX commercial solver. A numerical analysis on a test case illustrates the model formulation and the proposed model.

Key Words: Logistics, Reverse Logistics, Facility Llocation, End of Life Product, Location Problem, Mixed Linear Program

1. INTRODUCTION

Logistics is a vast field. Classical definitions of the word "LOGISTICS" appear in several works: "Greek mathematicians called logistics the art of calculating". In our context, logistics is "the art of transferring and transforming matter and information together and Just-in-Time with the permanent concern about the safety of people and goods, and preserving the environment". In large industrial companies "we can see that upstream logistics (supplies), often linked to the manufacturing logistics, differs from downstream logistics, within which distribution and after-sales often come under different services and circuits. Furthermore, downstream from consumption, developed "return" logistics complete the circuit. Logistic integration does not result in its organisational unification… Integrated logistics is a notion rather than an operational reality." The notion of integrated logistics for an industrial company brings together three aspects:

- Integration of industrial management technologies,
- Integration of safety and the environment in the production system,
- Finally, integrating the partners in view of searching for outside skills.

The company-network concept requires a scattered productive organisation in which searching for physical flows – and information flows – is quite complex. This complexity stems from the nature of the flows dealt with and also from the different environments called upon in order for this organisation to be successful. The production modes differs according to the company network's mesh, the distances that separate them, etc.

Reverse logistics can be defined as the reverse process of logistics [1]. Traditionally, reverse logistics has been viewed primarily as the process of recycling products. Today, definitions vary depending on what company or segment of industry is attempting to de0ne it. Retailers see reverse logistics as a way to get product that has been returned by

a consumer back to the vendor [2]. Manufacturers tend to view reverse logistics as the process of receiving defective products or reusable containers back from the user. The Council of Logistics Management (CLM) defines reverse logistics as “The process of planning, implementing, and controlling the efficient, cost effective flow of raw materials, in-process inventory, finished goods and related information from the point of consumption to the point of origin for the purpose of recapturing value or proper disposal” [3]. Reverse logistics generally involves events necessary to retrieve, transport and dispose of goods. These goods are moved backward from the consumer and the process includes the information flows associated with tracking and credit processes.

Reverse logistics focuses on the backward flow of materials from customer to supplier (or alternate disposition) with the goals of maximizing value from the returned item and/or assuring its proper disposal [4]. This may include product returns, source reduction, recycling, materials substitution, reuse of materials, waste disposal, refurbishing, repair, and remanufacturing. Reverse logistics processes–and reverse logistics research–has traditionally emphasized green logistics, i.e., the use of environmentally conscious logistics strategies [5]. While environmental aspects of reverse logistics are critically important, many firms are also recognizing the economic impact of reverse logistics [6]. Recent research suggests that companies can recapture value through an efficient and effective returns process [7].

Three types of decisions are involved in the decision problem related to the design of the reverse logistics network: the first concerns the sites facility location. The second concerns the flow of matter and information between these entities. Finally, the third is investment in labor and equipment in each of these facilities. In literature, these three categories of decisions refer to the problems of facility location, allocation and capacity [8]. For the facility location decision, it usually means selecting the most appropriate among previously identified potential sites in order to optimize one or more objective functions. In our research work, we focus specifically on modeling the problem of sites facility location in a reverse logistics network for product end of life.

[9] address the problem of localization in two approaches. The first is to add reverse logistics to a network of existing logistics while the second is to make a new logistics network. It is in second position that we're interested. Specifically, we seek to determine:

- The sites to open or close from a set of previously defined sites.
- The flow of material from these sites.

The decisions mentioned above are taken to minimize the cost of products recovery at the end of life. We wish to solve the problem of site facility location site in a reverse logistics network for various times of time considered in strategic planning. The inclusion of such an element means to solve a multi-time step problem: decisions taken at a given time are related to those taken in previous times and take account of future needs.

In the following sections, a literature review and related research work are illustrated in Section 2; this is followed by Section 3 which provides a discussion of our research problem, the conceptual model and the formulation model using Mixed Linear Program; In section 4 we present an illustrative example; Section 5 concludes the paper and provides suggestions for future research.

2. LITERATURE SURVEY

The facility location problem for the reverse logistics network has been the subject of several studies. One of the first models to localize the center of recovery is that proposed by [10]. They describe a management system for solid waste in Lambardy region (Italy) including collection, transportation, recycling and disposal. They use a multi-objective model. [11] Propose a model to minimize the total treatment cost of reusable containers using a special case of a localization classic model. It is a mixed linear program model. [12] Present a model for the spent recycling in the Netherlands in order to minimize the total cost of recovery network.

[13] Describe a Mixed Linear Program model for secondary products (uses) recovery. They assume that the quantity of secondary products is proportional to the amount of primary (new). In addition, they assume that returns are not necessarily returned to the outlet that delivered the product of departure, they can be returned at any open site.

[14] Present a linear programming model for the design of a network of recovery of the end of life products. This model is composed of several collection sites, a treatment site and several clients whose returns are known. The problem is to determine the number of collection sites and to initiate treatment in order to minimize the total cost of distribution around. They assume that returns can be routed directly to the treatment center without the intermediary of a collection center, the capacity is limited.

[15] Propose a multi-objective linear model for the recovery of obsolete computers in New Delhi. It adds the transport of hazardous materials risks between collection sites of treatment and risks in the different sites that constitute the network.

[16] Propose a linear programming model to give decision support to determine the collection sites, recycling and landfill open for the recovery of waste materials while limiting the capacity of sites. It aims to minimize the operational costs of the logistics network for product recovery at the end of life.

[17] Propose a linear programming model to locate sites in a reverse logistics network. These intermediate centers where used products are disassembled, cleaned and sorted to be transported to the remanufacturing sites (remanufacturing centers) in which the parts from the used products are used to manufacture new products.

When we review the literature on the facility location of sites in a reverse logistics network, we find that the models developed so far are based on a classical model of locating warehouses which are added one or two elements for reverse logistics as capacity, number of facilities open, non-negativity of decision variables, on the one hand. On the other hand, we note that the majority of models are single-time which cannot measure the impact of long-term decisions. Note also that most models proposed in the literature were developed for a reverse logistics network structure (no authorization flow between sites). Some models are easily adaptable from one network to another. Finally, they do not reflect environmental costs (emission of toxic gases) generated by hazardous materials.

3. PROBLEM STATEMENT

Most location models developed so far are models of single-product or single time. Indeed, some models are not adaptable for a network to another. Moreover, they do not take account of dynamism of reverse logistics program. To overcome these drawbacks, we propose a generic model multi-product and multi-time site locations for the reverse logistics of products at the end of life in order to minimize logistics costs. The proposed model can be used to solve the facility location problem of sites for varied structure networks.

The proposed model refers to the structure of the reverse logistics network shows in Figure 1. In this network, the company gets the products at the end of life returned by its customers through its collection sites. After their yards, they are transported to treatment sites. Some will be disposed of in landfill (e.g. hazardous materials). Further, they will be recycled (metal and plastic). Once processed, finished products from the recycling are used for the manufacture of new products which will then be offered to consumers and consumed.
To specify the study scope and facilitate model formulation, four assumptions and simplifications in the proposed model formulations are postulated as follows:

- The location of potential sites for the collection and treatment is known at time t.
- The costs of opening the site and transportation costs are known in advance.
- The capacity of each site is limited to the time.
- The cost of investment and divestiture of a portion of capacity at a site from one time to another are fixed.

- The various costs considered in the different nodes are: opening site cost and cost of unit transportation of products at the end of life...
- Several products at the end of life to be recovered by the company.
- No storage in the collection site

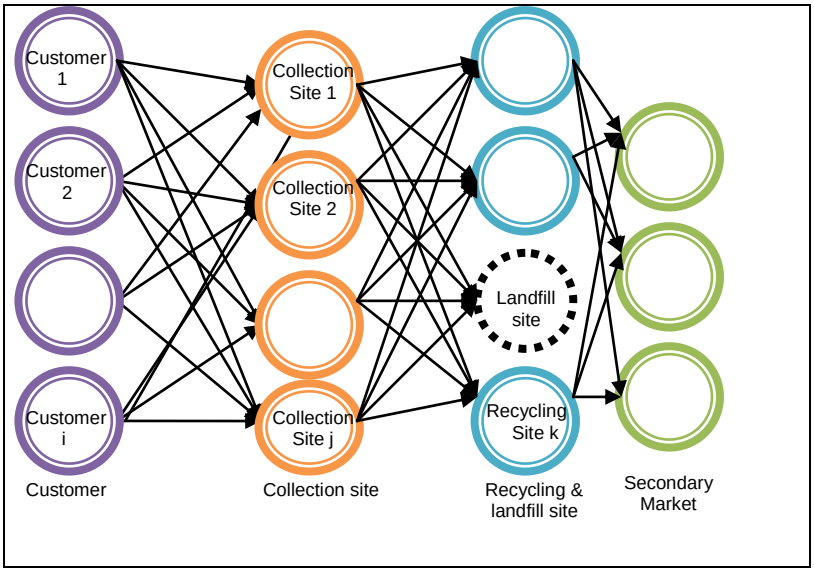

Figure 1: Reverse logistics network Structure for product end of life.

The proposed model aims to determine the sites to open or to close each time and the flow of goods between the different sites that make up the reverse logistics network (site collection, site recycling and landfill).

Indices

p	End of life Product index, p = {1, . . .,P}
i	Customer, i = {1, . . ., I}
j	Potentiel collection site, j = {1, . . ., J}
t	Time time, t = {1, . . .,T}, (T: planning horizon)
k	Potentiel Recycling site, k= {1,…., K} .
k'	Potentiel landfill site, k'= {1,…., K'} .

Parameters

F_{jt}	Fixed cost of collection site j opening in time t
F_{kt}	Fixed cost of recycling site k opening in time t
$F_{k't}$	Fixed cost of landfill site k' opening in time t
C_{pijt}	Cost of end of life product p transporting from customer i to the collect site j at time t
C_{pjkt}	Cost of end of life product p transporting from collection site j to the recycling site k at time t
$C_{pjk't}$	Cost of end of life product p transporting from collection site j to the landfill site k' at time t
B_{jt}	Collection site j capacity at time t
D_{kt}	Recycling site k capacity at time t
$E_{k't}$	Landfill site k' capacity at time t
$Y_{\max}$	Maximum number of collection sites to open

$Z_{\max}$	Maximum number of recycling sites to open
$W_{\max}$	Maximum number of landfill sites to open
$Y_{\min}$	Minimum number of collection sites to open
$Z_{\min}$	Minimum number of recycling sites to open
$W_{\min}$	Minimum number of landfill sites to open
G_t	The sum of the customer returns at time t
M	A constant size

Decision variables

Y_{jt}	Binary variable equal to 1 if site j is open at time t
Z_{kt}	Binary variable equal to 1 if site k is open at time t
$W_{k't}$	Binary variable equal to 1 if site k' is open at time t
X_{pijt}	End of life products quantity stored at customer i and transported to the collection site j in time t.
X_{pjkt}	End of life products quantity to recycled and transported from the collection site j to recycling site k at time t.
$X_{pjk't}$	End of life products quantity to eliminate and transported from the collection site j to landfill site k' at time t.

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

$$Min\ A = \sum_j \sum_t F_{jt} Y_{jt} + \sum_k \sum_t F_{kt} Z_{kt} + \sum_p \sum_i \sum_j \sum_t C_{pijt}\ X_{pjk} + \sum_p \sum_j \sum_k \sum_t C_{pjkt}\ X_{pjkt} + \sum_p \sum_j \sum_{k'} \sum_t C_{pjk't}\ X_{pjk't} \tag{1}$$

Subject to

$$\sum_j X_{pijt} \geq G_t \qquad \forall p, \forall i, \forall t \tag{2}$$

$$\sum_j X_{pijt} = \sum_k X_{pjkt} + \sum_{k'} X_{pjk't} \quad \forall p, \forall i, \forall t \tag{3}$$

$$\sum_p \sum_i \sum_j X_{pijt} \leq B_{jt}\ Y_{jt} \qquad \forall k, \forall t \tag{4}$$

$$\sum_p \sum_i \sum_k X_{pjkt} \leq D_{kt}\ Z_{kt} \quad \forall j, \forall t \tag{5}$$

$$\sum_p \sum_i \sum_{k'} X_{pjk't} \leq E_{k't}\ W_{k't} \quad \forall j, \forall t \tag{6}$$

$$\sum_p \sum_i \sum_j X_{pijt} \leq M\, Y_{jt} \quad \forall k\ ,\ \forall t \tag{7}$$

$$\sum_{p}\sum_{i}\sum_{k} X_{pjkt} \leq M\, Z_{kt} \qquad \forall j,\ \forall t \tag{8}$$

$$\sum_{p}\sum_{i}\sum_{k'} X_{pjk't} \leq M\, W_{k't} \qquad \forall j,\ \forall t \tag{9}$$

$$Y_{\min} \leq \sum_{j} Y_{jt} \leq Y_{\max} \qquad \forall t \tag{10}$$

$$Z_{\min} \leq \sum_{k} Z_{kt} \leq Z_{\max} \qquad \forall t \tag{11}$$

$$W_{\min} \leq \sum_{k'} W_{k't} \leq W_{\max} \qquad \forall t \tag{12}$$

$$Y_{jt}, Z_{kt}, W_{k't} \in \{0,1\} \quad \forall j, \forall k, \forall k', \forall t \tag{13}$$

$$X_{pijkt}, X_{pjkt}, X_{pjk't} \geq 0\ \forall p, \forall i, \forall j, \forall k, \forall k', \forall t \tag{14}$$

The main objective of this mathematical model is the determination of the collection and treatment sites (site of recycling and landfill) location in each time and the flow between these sites. This model aims to minimize the costs of end of life products recovery. The mathematical model specifies is the variety of end-of-life product and multiple times.

The constraint (2) describes that all the end of life products are collected by the company. Float balance between the different sites is assured by constraint (3). The respect of the available capacity is provided by the constraint (4, 5, 6). Constraints (7), (8) and (9) ensure that if a site is closed, the flow of incoming and outgoing products are zero, M is a size constant. The respect of opening site constraint is provided by the constraint (10, 11, 12). Constraint set (13) check for binary variables and the last constraint s (14) check for the non-negativity of decision variables.

4. RESULTS AND DISCUSSIONS

We apply our model on a dataset taken from the literature on the reverse logistics of electronic products at end of life in India, Indeed, electronic products end of life will reach 217 440 tones in 2010 in India [15]. Using a numerical example, we will illustrate how the model works in the proposed framework a gain some insights into the proposed model. A small set of data is prepared reflecting the real business situation. Indeed, the company recovers the end of life product of its customers to be sorted and disassembled in the collection sites. Hazardous products will be disposed of in landfills. Materials will be transported to recycling sites. The reverse logistics network for the application is composed of: 3 customer, 9 collection site, 7 recycling site, 2 landfill site, 4 times' time and 6 end of life products. We obtained the results using a Windows XP, Pentium 4, 2.4 GHz and 160 GB of memory (Figure 2). Figure 3 shows potential site of collection, recycling and landfill to open in every time.

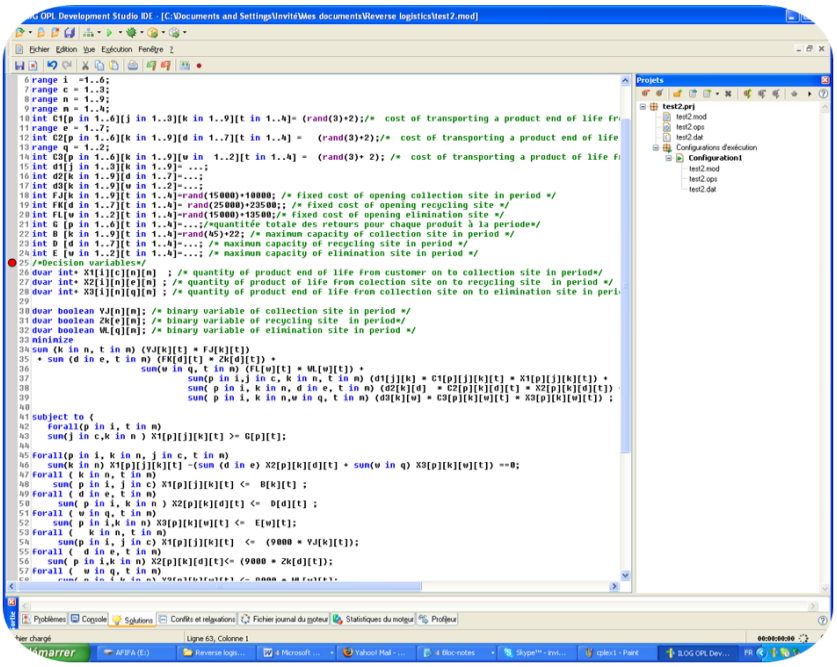

Figure 2: Implementation of the proposed model with the case of application using the CPLEX.

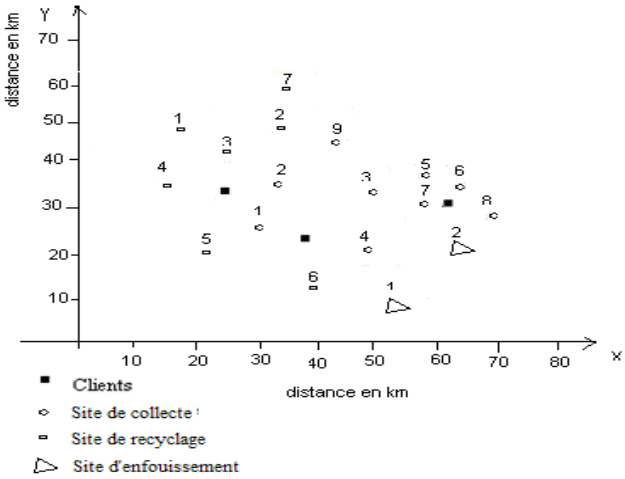

Figure 3: Potential site of collection, recycling and landfill to open in every time.

The results of the case of application considered are shown in the Table I.

Table I: Numerical results of the application.

Constraint number	Total variable	Binary variable number	Execution time (s)	Optimal cost
885	2665	72	33.5	693150

The optimal cost is found 693,150 including three collection sites, three recycling sites and two landfills are open. CPLEX found the optimal solution after 33.5 minutes second. In the time 4, three collection sites will be open because the quantity of returns less than in the first time. Thus, the proposed model allows taking into account the dynamism of a reverse logistics system. Moreover, we note that when we increase the number of times considered in the strategic planning, logistics costs are declining. This can be explained by increasing

the quantity of products at the end of life recovered. However, we note that the costs increase significantly in establishing a strategic planning on 9 times (Figure 4).

5. CONCLUSIONS

Compared to early literature on addressing end life recovery and facility location, the model found in this study has two distinctive features. First, by coordinating the critical activities of reverse logistics management, the proposed method addresses the classical network of end life product treatment problem with a generic model. . Second, In this work, we established a multi-product and multi-time location of sites for the reverse logistics of the end of life products. The proposed model can be applied to varied structure reverse logistics network. It can determine the state of sites, their openness, closure, available capacity and material flow between the various entities of the logistics network. All decisions shall be taken to minimize logistics costs. However, we considered that the returns quantity is determinist and that investment in the capacity of a site is fixed. In literature the problem of facility localization is an NP-hard problem. To solve the mathematical program, we use the evaluation and separation process located in a commercial solver Cplex. The modeling problem of the facility location in reverse logistics network sites is an open area of research.

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