Weighted Flow Distribution Model of the Reverse Logistics System

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***Abstract*—This paper provides a weighted flow distribution in the application of reverse logistics in a production unit. For the better understanding of reverse logistics, the definition and features of reverse logistics are first introduced. The difference between the forward and reverse logistics system is briefly tabulated. The classification of the reverse logistics on the loop basis is defined thereafter. The reasons to improve reverse logistics management system are explained. A mathematical formula for the optimization is derived with respect to various parameters which was further derived into weighted formula for providing preferences for transportation etc.**

***Index Terms*—Flow Distribution Optimization, Reverse Logistics.**

I. Introduction

Recycling is known to most of the people as an activity in domestic waste separation with a few tangible or financial benefits. Nevertheless, material reclamation flows play important roles in a number of industries. The development of more, complex systems that can handle both a greater volume and a wider variety of waste materials is a pursuit crucial to the establishment of a sustainable society besides a potentially lucrative source of new economic growth [1].

A Reverse Production System abbreviated as RPS includes collection, sorting, remanufacturing, and refurbishing processes for end-of-life products. An RPS infrastructure design prescribes the facility location of collection and processing sites and involves a decision process for evaluating and selecting alternatives under multi-criteria evaluation and uncertainty regarding the external environment [2].

Bidirectional supply chains or reverse supply chains have attained increasing importance, especially in two contexts, one being the case of supply chains that also handle repairs as in any maintenance supply chain and the second being the case of supply chains that include recycling, whether for environmental or economic reasons. Unlike single-directional supply chains, optimization based approaches to bidirectional supply chains are computationally intractable for realistic supply chains (partly owing to the property that stochastic disturbances enter at both ends of a bidirectional supply chain), and also necessitate simplifying assumptions on manufacturing times, repair times, demand profiles, etc. [3]

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A. Difference between forward and reverse logistics system

TABLE I
Comparison between Reverse and Forward Logistics [4]

S. No.	Factors	Reverse Logistics	Forward logistics
1.	Quantity	Small Quantities	Large Quantities of standardized items
2.	Information tracking	Combination of automated and manual information system used to track items	Automated information system used to track items
3	Order cycle time	Varies from medium to long order cycle time	Short order cycle time
4.	Product value	Moderate to low product value	High product value
5.	Inventory Control	Not focused	Focused
6.	Priority	Low	High
7.	Cost Elements	More hidden	Quite Transparent
8.	Product flow	Two-Way (Push and Pull)	One-Way (Pull Only)
9.	Channel	More Complex and diverse	Less complex

B. Types of Reverse Logistics

Broadly, there are two types of reverse logistics classified on the basis of the degree of the openness in its network. One of the two classifications is Open-loop structure and the other one is Closed-loop System.

Open-Loop Reverse Logistics System

In this case the manufactured products do not return to the original manufacturers or suppliers. The products are taken away by the third party logistics party for the purpose of waste reduction, resale etc as shown in figure 1. E.g. the recycling for parts and raw materials is generally open-loop structure, i.e. the product will not be back to the original manufacturers or suppliers, not used by other manufacturers [5].

Closed-Loop Reverse Logistics System

In this case products get returned to the original manufacturers or suppliers, by any means, for the purpose of repair, renovation or reuse. Reuse of glass bottles falls under this category as shown in figure 2. In need of repair or renovation it usually points the original source, belonging to the closed-loop structure. In reality, in order to better establish the overall network, a composite structure is used in the household appliance reverse logistics network design [5]

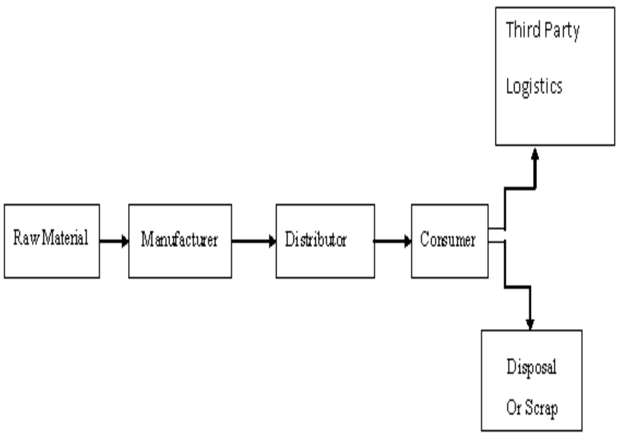

Fig. 1. Open-Loop Reverse Logistics System [6]

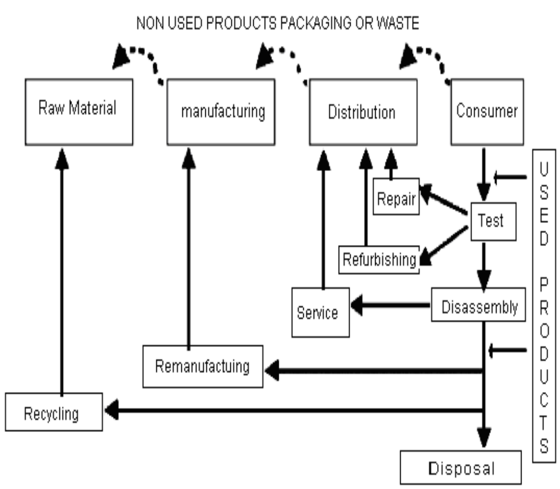

Fig. 2. Closed Loop Supply Chain

II. Mathematical model for the application of reverse logistics in optimization of production unit

Consider the following schematic diagram representing the combined inflow and outflow of the manufactured products in which i denotes manufacturing plant, j denotes distributors and k denotes the customer.

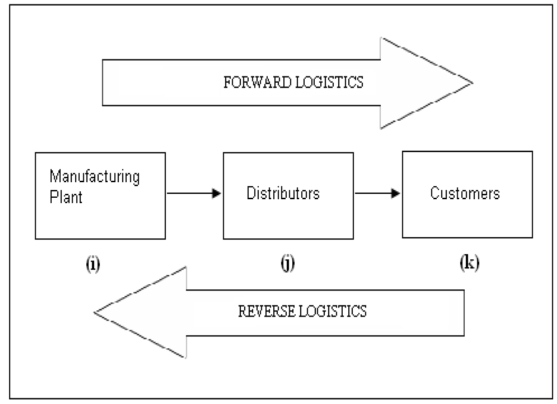

Fig. 3. Bidirectional Movement of Products in the Plant

The following are the number of variables that influence the production plant:

1. A_{ij} = number of items inspected and distributed from manufacturing plant i to distributor j in one day.
2. C_{min}=minimum production capacity of the plant
3. C_{max} = maximum production capacity of the plant
4. I_{max} = maximum capacity of the inspection unit
5. I_{min} = minimum capacity of the inspection unit
6. $\sum A_{ij}$ = total number of products sent from plant i to j (=1, 2, 3, …)
7. t_1 = time taken by a product to be cleaned, inspected and refilled.
8. t_{ij} = average time taken to inspect one product.
9. $\sum A_{ij} * t_1$= total time taken to manufacture products in a day.
10. t_{jk} = average time taken by product to reach a customer's end from distributor
11. t_{ji} = time taken by a unit product to reach at manufacturing plant from distributors.
12. $\sum A_{kj}$= number of products returned in good condition

From the above conditions it can be easily derived that the products will get returned to the source itself by the time

T = (average time taken by products to move from manufacturing plant to distributor after being inspected) + (average time taken by products to move from distributor to consumer) + (average time taken by products to move back from consumer to distributor and then back to the inspection unit)

$$T = t_{ij} + t_{jk} + t_{kj} + t_{ji}$$

As the time taken by a unit product to be inspected is t_1 so applying unitary method we can obtain that the number of new products manufactured in time T will be = T/t_1 i.e $(t_{ij} + t_{jk} + t_{kj} + t_{ji})/ t_1$ which, in other words can be stated as the quantity of new products required before the return of the same lot. But $(1-\mu) \sum A_{ij}$ is the number of products returned and rejoined the manufacturing process.

Hence $\{(t_{ij} + t_{jk} + t_{kj} + t_{ji})/ t_1\}- (1-\mu) \sum A_{ij}$ = number of new products that need to be refilled after the returned lot of previously sent products rejoin. So the hiring will be

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reduced depending linearly on the quantity of the returned lot.

So the objective is to minimize the above equation so that after the first running day of the plant the production of products is reduced which, obviously, require the maximization of the returned products.

$$\mathbf{N_a} = \{(t_{ij} + t_{jk} + t_{kj} + t_{ji}) / t_l\} - (1-\mu) \sum A_{ij}$$

where subscript 'a' represents the number of route by which the product is sent. Constraints:-

$\sum A_{ij} \leq C_{max}$
$\sum A_{ij} \geq C_{min}$
$\sum A_{kj} = (1-\mu)*\sum A_{ij}$
$1\leq \mu \leq 0$ where μ is defined as the ratio of number of products in non usable to the number of distributed.
$\sum A_{ij} \leq I_{max}$
$\sum A_{ij} \geq I_{min}$

Weights may be given to the routes causing major requirements. Let us suppose the there are five routes the product is sent to. So it will have N_1, N_2, N_3, N_4 and N_5 as its new product requirements. The maximum of the above may be made the basis for giving weights which will rule the preference for the distribution to cover as much as requirement possible.

Mathematically it can be given as:-

$W_a = N_a/\{\max(N_1, N_2, N_3, \ldots N_a)\}$ and the preference can be given in the order giving maximum value of W_a priority to the others.

If net production in a day is P then it can be distributed for any route 'a' as:

$P_a = W_a * P$ i.e

$P_a = [N_a/\{\max(N_1, N_2, N_3, \ldots N_a)\}]/P$

III. OBSERVATIONS AND CALCULATIONS

The required data may be obtained and tabulated as shown below:-

TABLE II
HIRING CAPACITY OF THE PLANT IN NUMBER OF PRODUCTS /YEAR

C	HIRING CAPACITY (number of products per annum)
C_{max}	A
C_{min}	B

TABLE III
INSPECTION CAPACITY OF THE PLANT IN PRODUCTS PER UNIT TIME

I	INSPECTION CAPACITY
I_{max}	C
I_{min}	D

TABLE IV
DIFFERENT PARAMETERS FOR DIFFERENT ROUTES

	Route I	Route II	Route III	Route IV
t_{ij}	X	X	X	X
t_{jk}	X	X	X	X
t_{kj}	X	X	X	X
t_{ji}	X	X	X	X
t_l	X	X	X	X
μ(%)	X	X	X	X
A_{ij}	X	X	X	X
N	X	X	X	X
W_a	X	X	X	X
P_a	X	X	X	X

Where A, B, C, D and X are prospective values which may be obtained on conducting case study using this method.

IV. CONCLUSIONS

From the above tables the relevant charts can be obtained and thereby revealing a particular route number(s) requiring major attention in terms of preference for more transportation requirement, product supply etc. as it will make the revenue better and ensure more reuse of the product and saving a lot to the environment.

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