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A COLLABORATIVE APPLICATION OF AHP TO ENHANCE A ROUTING MODEL FOR LOGISTICS AND REVERSE LOGISTICS

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ABSTRACT

The routing of material transport determines the efficacy of logistics network. Due to the increased usage of plastics in the country like India, large quantities of HDPE bottles are generated every year. HDPE being formed from petroleum, production of new bottles cost a significant effect to the global warming. Therefore rework of defective bottles is necessary. The obstacles faced during the rework process are the uncertainty involved in collection of returned bottles from different manufacturing units, at the same time the diversity in the variety, quantity, quality of the products. This necessitates for an effective and well-organized reverse logistics network to return the remanufactured products. The objective of this work is to exemplify the role of transportation in reverse logistics for the purpose of further improvement and to assist the HDPE bottle manufacturing industries, having problems in efficient routing of defective goods. The proposed model is solved using Arena optimization solver which provides the decisions related to the utilization capability of the manufacturing units and the allocation of the corresponding product flows. Energy analysis of the model is also presented to find the energy of transportation and to minimize the cost of transportation.

Keywords: logistics, reverse logistics, energy analysis.

1. INTRODUCTION

According to the convention of supply chain management professionals, the supply chain management has evolved to meet the changing requirements of an inclusive supply chain. SCM encompasses the planning and management of all activities involved in sourcing and procurement. In order for a supply chain to be profitable, quality from suppliers must be considered on the decision making process [1].

1.1 Logistics

The logistics management is an essential part of SCM that plans, implements and controls the efficient movement of flow of commodities, services and interrelated information between the point of origin and the point of consumption in order to meet the needs. Supply chain Logistics influences National Economy (GDP, unemployment rate, inflation rate) factors either directly or indirectly [2].

Major activities of the logistics system include serving customers, product selection, quantification, procurement, inventory management, storage and distribution. Logistics has received great attention in the literature which covered the following areas: warehousing and facility location, inventory control, transportation/routing and scheduling, demand forecasting, production planning, and logistics system design. A thorough methodological review of SCM and logistics research is provided by Sachan and Datta [3].

1.2 Reverse logistics

Remanufacturing of used products is not a new term, but the scale and unique processes have made remanufacturing an important subject in research. The studies related to remanufacturing have increased after the 1980s, and there have been a lot of research studies conducted on the subject from the 1980s onward [4].

Remanufacturing systems offer potential advantages, including increased profitability through reduced material requirements, reduced acquisition cost, and improved market share based on environmental image [5].

An integrated supply chain framework was presented to demonstrate reverse flows and recovery options such as repair, refurbishing, remanufacturing, recycling, etc. [6]. The development of research in environmentally conscious manufacturing and product recovery was presented and a state-of-the-art survey of the published work in that area was provided [7].

The main activity in the reverse logistics is the collection of the products to be reworked and the redistribution of the processed goods. Though this looks identical to the forward logistics, there are many problems while collecting back the products.

Reverse logistics is an emerging technique of SPM. The main issue in designing a network is the number of layers in the network such as, the location of depots, integrating reverse logistic model with the supply chain, making alternate drop points, inventory balance between different collecting points, finally analysing the cost involved in implementing the model. The benefits of reverse logistics are increased revenue from secondary sales and identifying slow selling products. With proper implementation of reverse logistic network for the products that often need rework, operating cost can be reduced.

1.3 Genetic algorithm

GA is a search algorithm based on the biological method of natural selection. According to natural selection the fittest individuals in a population will survive and reproduce individuals for the next generation. Similarly in GA the fittest individuals are selected and they undergo reproduction to produce favourable characteristics for the

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next generation. The algorithm undergoes a number of iterations until a stopping criterion is reached which ensures the algorithm to converge to the local or global minimum.

2. AHP

Analytic Hierarchy Process (AHP), since its invention, has been a tool at the hands of decision makers and researchers; and it is one of the most widely used multiple criteria decision-making tools.

AHP method aggregates various facets of the decision problem using a single optimization function known as the objective functions. The goal of AHP is to select the alternative that results in the greatest value of the objective function.

The speciality of AHP is its flexibility to be integrated with different techniques like Linear Programming, Quality Function Deployment, Fuzzy Logic, etc. This enables the user to extract benefits from all the combined methods, and hence, achieve the desired goal in a better way [8].

The AHP has been used to assist decision making in applications ranging from bridge-design selection to product-pricing-strategy choice [9].

3. PROBLEM DESCRIPTION

HDPE Plastics are basically formed from petroleum and production, utilization and disposal of petroleum products cost a significant effect to the global warming. The discussion of HDPE is done because the paper has a significant role for HDPE manufacturing and rework process and also how this affects the supply chain is discussed.

The company has 5 different types of oil products and these are being manufactured by 14 different manufacturing units rented by the company. The company uses third party logistic network for the movement of raw materials and finished products.

The problem focuses during the bottle manufacturing process. During the extrusion blow molding process, bottles may get rejected to some quality issues like pinch off, and as soon as possible the rejected bottles are processed through a grinding machine, turning them into pellets. During the next stage of screen printing process, rejection of bottles may occur due to misalignment of words, over usage of ink; in this situation the rejected bottles are sent to a separate cleaning processed unit where the bottles undergo 5 stages of cleaning.

This section describes a specific type of remanufacturing process; the obstacles faced during the rework process are the uncertainty involved in collection of returned bottles from different manufacturing units at the same time, this compromises the variety, quantity, quality of the products, secondly the necessity for an effective and well-organized reverse logistics network is needed to return the remanufactured products.

Since there is only one pelletization unit for all the rejected bottles from the 14 manufacturing units there are several issues regarding the assortment procedure for selecting the particular manufacturing units rejected bottles and also the capacity of the pelletization unit is low i.e., 300kg/day. Due to this problem the company is facing an inventory lag and is unable to meet the time requirement.

Indices

m for manufacturing unit; $m \in M$
r for pelletization unit ; $r \in R$
t for time period ; $t \in T$
k monthly demand; $k \in K$
i inventory in pelletization unit; $i \in I$

Parameters

R remanufacturing cost
F_m fixed transport cost for manufacturing unit
C_m maximum capacity of manufacturing unit
S_m shortest distance from manufacturing unit to pellet unit
Q_m quality produced by manufacturing unit

Decision variables

Y_{mt}, volume of product transferred from manufacturing unit m, at time t.

Z_{mt}, time taken to route from manufacturing unit m, to pellet unit, at time t.

Objective function:

MIN = TI – (RBS+PBS+RC+VRT)
Total inventory
$TI = \sum_t \sum_m i\, Z_{mt} Y_{mt}$
Raw material batch size
$RBS = \sum_t \sum_m C_m Y_{mt} Q_m S_m$
Pellet batch size
$PBS = \sum_t Y_{mt} S_m$
Transportation cost after rework
$RC = \sum_m R\, S_m$
VEHCILE ROUTING DAYS
$VRT = \sum_t Z_{mt} S_m$

Constraints

The rework bottles are sent to the particular manufacturing unit based on the shortest distance and quality of manufacturing unit.

$I \geq S_t\ Q_m,\ \forall\, t \in T;\ \forall\, m \in M$

The manufacturing unit should not exceed the maximum capacity

$K \leq C_m S_t\ ,\ \forall\, t \in T;\ \forall\, m \in M$

The above model is solved using MAT LAB for the parameters presented in Table-1.

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Table-1. Data collected from industry.

S. No.	Manufacturing units	Manufacturing capacity	Distance from pellet unit (km)
1	Unit 1	90000	8.8
2	Unit 2	32000	13
3	Unit 3	32000	15
4	Unit 4	70000	18
5	Unit 5	40000	19.6
6	Unit 6	35000	20
7	Unit 7	20000	21
8	Unit 8	30000	23
9	Unit 9	26000	25
10	Unit 10	36000	34
11	Unit 11	40000	35.6
12	Unit 12	36000	36
13	Unit 13	15000	38
14	Unit 14	26000	227

4. RESULTS FROM THE ANALYSIS

In this paper, we present MATLAB as an optimization solver for solving the reverse logistics network for product recovery.

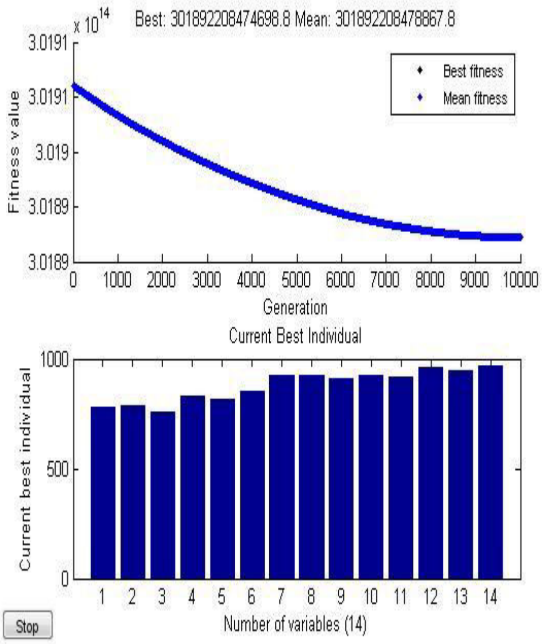

Figure-1. Results from MATLAB.

4.1 Ahp matrix formation

Creating a matrix using AHP involves various steps and depending on the problem, criteria and parameters the matrix is formed.

Based on the details given by the company and keeping the rules in mind the AHP matrix was developed and it was found to be consistent and the hierarchical ranking of the manufacturing units were done

Based on the formed matrix, a vehicle routing model for the AHP matrix was developed and the results were simulated.

5. SIMULATION USING ARENA

The following computerized model created in ARENA software shows the operations performed in a bottle manufacturing unit where the quality of the bottles are monitored at different stages in the process. As shown in Figure-1, the raw materials arrive at the manufacturing unit from the warehouse where it undergoes Extrusion Blow Molding and the rejected bottles (due to pinch off) are sent through a grinding process where they are broken down to pellets and sent for rework. At the next stage, the bottles are sent through a screen printing process and the rejections here are sent to a pelletization unit to form pellets and are taken back to the manufacturing unit. The final stage is where the bottles are taken to the oil filling unit. On running the simulation for the process flow model, a comparison is derived between the overall operational utilization and the scrap generated. Thus, implementing the ARENA software has proven to be conducive towards effectively managing the process flow and assuring quality in production.

6. RESULTS FROM ARENA SIMULATION MODEL

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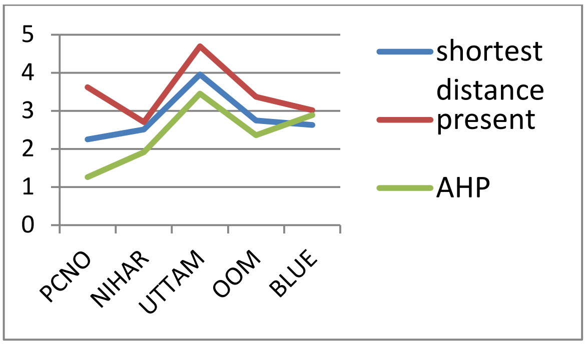

Figure-2. Transfer time.

The above Figure shows the product transfer time that is taken by the three different scenarios, in the x-axis the different products are shown and in the y-axis is the time in hours is shown and it evident from this graph the AHP model was found have better product transfer time performance when compared with the other scenarios.

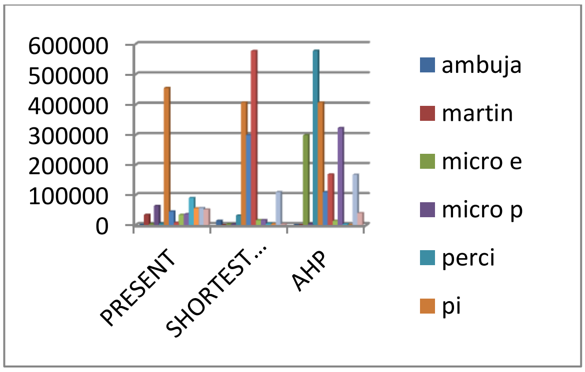

Figure-3. Utilization of product.

The above bar chart shows the utilization capability of the manufacturing units for those returned pellets for three different scenarios generated using arena. The results shows the AHP model was found to be utilizing more pellets when compared with the other scenarios.

7. EXERGY ANALYSIS

The energy of a resource is a measure of its usefulness or quality or ability to drive tasks. Energy analysis is commonly used in the assessment, design and improvement of energy systems and processes.

7.1 Results from energy analysis for transportation sector

As a fundamental measure of the thermodynamic deviation of the considered system from its environment, energy is thus equal to the maximum amount of work the system can perform when brought into thermodynamic equilibrium with its reference environment. To evaluate the energy flows associated with a vehicle, it is reasonable to take the standard atmosphere as the reference environment. For fuels used in transportation devices, the physical energy is negligible, compared to the chemical energy well estimated as (Kotas, 1985)

$\varepsilon = \gamma * LHV$

with γ standing for the exergy factor (the exergy-energy ratio) based on LHV (lower heating value of fuels, also called net calorific value, excludes the latent heat of the water vapor when the heating value of fuels is measured), which is the energy input for the considered process. ε denotes the specific exergy.

Exergy efficiency

The exergy efficiency is given by the for formula

$\Psi = \eta / \gamma$

Where γ is the exergy factor for lower heating values for the type of fuels used. η represents the first law of thermodynamic efficiency.

The calculation part was done using the above expressions and the exergy utilized by each manufacturing units were observed.

Table-2. Values used.

Exergy factor	1.06
Energy input	42652 kJ/kg
Air density	1.25 kg/m^3
Coefficient of drag friction	1.2

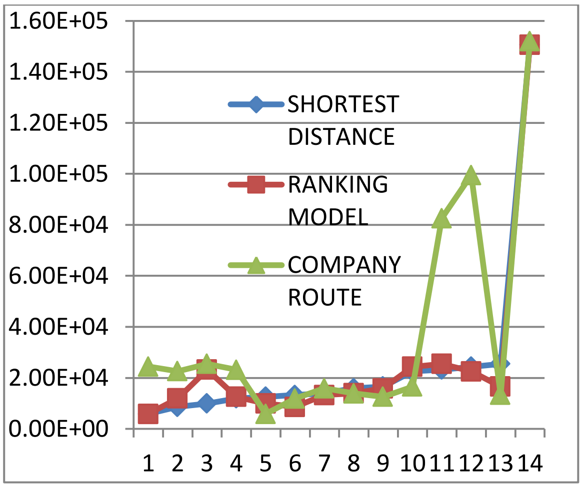

Figure-4. Results of energy.

The above graph show the energy increasing at a steady rate from the starting to the end, this is due to the arrangement of the manufacturing unit on the basis of their shortest distance, it is understandable from the graph that the energy is less consumed for a short distance and consumed in higher rate for a longer distance, but based on distance criteria alone the vehicle routing cannot be done and therefore based on AHP criteria may be considered as the best way of taking pellets for a routing option.

8. CONCLUSION

For the purpose of reducing global warming, more HDPE manufacturing industries are engaged in the product recovery. Recovery options include the limited use of petroleum raw material by some of its parts subjected through repair and remanufacturing or recycling. In this paper, reverse logistics network for product recovery is designed to optimize the routing of the remanufacturing operations. Since the location/ allocation decisions of the initial collection points play a key role in successful operations of reverse logistics, a objective function is developed for analysing such decisions in the remanufacturing system. The AHP model is solved using ARENA optimization solver and promising results in terms of the utilization capability of the manufacturing units were obtained.

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