7.1 Introduction

Vehicle routing, which is effective and efficient, is a dominant aspect of supply chain management in general and RL in particular. It is also a right step towards the fuel conservation and environmental concern in disposing used commodities. Economics of Logistics and transportation plays a major role in deciding the competitiveness of the product, either new or used, in the market. In order to reduce environmental impacts and the energy consumption, it is mandatory, more than desirable, for firms/companies to reduce the emissions and noise by way of reduced truck trips or finding shortest truck routes. With the upwards trends of fuel and logistics costs, manufacturing industries have little option other than keeping the cost of transportation lowest. Many organizations now started implementing lesser expensive and proper transport modes to keep the maintenance of supply chain cost to the minimum.

Proper handling of returned commodities to recover value without affecting the environment may need appropriate techniques or methodologies. This paper deals with the routing of vehicles with energy conservation as the agenda in value recovering method named as repair service work. It is done through a mathematical modelling of RL networking, in a multi-commodity environment. Here, the transportation of commodities to repair service facilities is given an in depth focus to reduce the energy use. The minimization of the distance travelled by the truck fleet, reduce the energy consumption by the trucks.

The distribution of goods based on road services in urban areas contribute to traffic congestion, generates environmental problems and in some cases results in high logistics costs (Barceló et al. 2006). Reduction in traffic congestion with efficient pick-up or delivery system is a must so as to reduce the fleet size and to maximize the load factor (Taniguchi et al. 2001). The present work is an attempt towards addressing the mentioned issue by way of introducing the concept of energy
conservation in RL network with ever increasing reverse flows. For this model, the vehicle routing for the transportation of the returned commodities are taken into account in detail. Vehicle routing is made only for the collection of returned commodities from the disposer market to the repair service facilities.

7.2 Vehicle Routing - A literature review

This problem belongs to the vehicle routing problems studied by a number of authors including Min, (1989), Mosheiov (1994), Nagy and Salhi (1998 and 2005), Salhi and Nagy (1999), Gendreau et al. (1999), Dethloff (2002), Gribkovskaia et al. (2001), Angelelli and Mansini (2002), Tang and Galvão (2002 and 2006), Süral and Bookbinder (2003), Wasner and Zäphel (2004), Gribkovskaia et al., (2007) and Hoff et al., (2006). Most of the works in vehicle routing problems with pickups and deliveries are based on heuristics. In few cases, the chosen algorithms are unable to solve instances of realistic sizes. For example, Süral and Bookbinder (2003) solve exactly small instances of a particular case of vehicle routing problem in which each customer has a pickup or a delivery demand, but not both, and hence is visited only once. Heuristics include classical procedures such as nearest neighbour or sweep constructive procedures, as well as improvement procedures making customer relocations.

7.3 Energy Conservative Measure in Reverse Logistics Network

Studies, in a repair service facility, show that the trucks pick the commodities, individually after getting the complaint from the customers or from the dispose markets. Therefore, the truck makes a number of trips, which may be equal to as many number of complaints received. Hence, the energy usage by the truck is proportional to the number of complaints. This also increases the emission and noise that add to the environmental pollution. With these observations, a methodology as detailed below is proposed in order to reduce the energy usage of the truck.

7.3.1 Objective

This work is different from the RL network given in the earlier chapters. Because, this model is concentrating on the transport of the returned commodities from the customer market into repair service facilities to conserve the energy used by the trucks through a vehicle routing algorithm. To analyze such a type of problem, a
network modeling of a single level, multi-commodity RL Network with Vehicle routing is formulated here. The network model is developed with the objective of optimizing or reducing the number of routes used to pick the commodities and to reduce the logistics costs.

7.3.2 The Proposed Methodology

Step 1: Complaints received by the repair service facility may be consolidated for a particular period of time (say one day).

Step 2: The consolidation of the complaints may be done with a fixed time frame (9am to 5pm).

Step 3: After the completion of the time, the commodities can be grouped based on specific areas or specific routes, the commodities belong or they can be picked.

Step 4: After grouping the complaints based on step 3, truck trips may be enabled to collect the commodities to repair service facilities, based on the capacity of the truck and distance to be covered. This lead to considerable reduction in number of truck trips and hence the energy use for the transportation of the commodities.

7.3.3 Framework of Vehicle Routing

The framework for the analysis of the RL network design is given below: Defective, different types of used commodities (multi-commodity), in varying quantities at various points of time are collected from the disposer market (Mk) and transported to repair service facilities (J). After service, the products are delivered back to the collection sites, i.e., to the reuse market (Mk). Transportation of commodities to the repair service facilities is considered as a vehicle routing problem, to optimize the routes followed during the collection of returns.
Fig. 7.1 shows the transport of the returned commodities from the disposer market or from the customer.

7.3.4 Factors considered

The factors considered for a successful RL vehicle routing are the number of commodities picked or customer served, the number of repair service facility locations and the number of possible routes and their distances, the cost of transportation, Boolean operator to indicate the status of the repair service facility (open or not).

7.4 Single Level Multi-Commodity RL Network Model with vehicle routing

Here, the modeling of vehicle routing for a single level, multi-commodity RL flow network is formulated, based on the problems which are taking place during the transportation of commodities from the customer market into repair service facilities. This modeling considers various factors as listed above while formatting the network.

In the stated situation the major consideration is deciding on the number of trips performed by the trucks of manufacturer’s repair service facilities so as to reduce the number of trips, and there by to reduce the total cost of transporting the commodities.
The main objective of this work is to develop a simple method for solving the real logistic problem considered, that is the picking of the commodities from the customer market to the repair service facility.

The objective function,

\[
\text{Min} \sum_{i=0}^{N} \sum_{j=0}^{N} C_{ij} X_{ij}
\]

Subject to the constraints:

\[
\sum_{i \in 1, i \neq j}^{N} X_{ij} = 1, \quad \forall j, j \in \{1, \ldots, N\},
\]

\[
\sum_{i \in 1, j \neq i}^{N} X_{ij} = 1, \quad \forall j, j \in \{1, \ldots, N\},
\]

\[
\sum_{i=0}^{N} \sum_{j=0}^{N} X_{ij} \leq |S| - 1
\]

\[
\sum_{i=0}^{N} \sum_{j \in T}^{N} X_{ij} \leq |T| - k
\]

Parameters:

N = number of customers or truck stops
Q = capacity of the vehicle
d_i = demand of customers i, i > 0,
C_{ij} = distance between the customers i and facility j

Variables:

\[
X_{ij, i \neq j} = \begin{cases} 
1, \text{if a truck goes from facility' j' to customer' i'} \\
0, \text{otherwise}
\end{cases}
\]

Where \( j \in \{0, \ldots, N\} \) being 0 the origin (the service facility).

T is set of customer and every set satisfies \( \sum_{i \in T} d_i > Q \)

“k” is the minimum number of customers that have to be taken from T to avoid overloading.
7.5 Algorithm Used

Clarke-Wright savings algorithm

Randomization: Instead of choosing the best pairing of routes at each step, one of the k best pairings, chosen randomly. Repeat several times and choose the best overall solution.

Improvement Heuristics: After an initial solution is built, various improvement heuristics are performed. These include the well-known 2-opt and Or-opt operations (the Or-opt uses group sizes of 1, 2, and 3), as well as a swap operation in which two customers on different routes may be removed from their routes and inserted into the opposite route.

Testing

The model developed in this work has been applied to a real situation. The Table 7.1 shows the energy conserved by the truck for collecting the commodities on a particular day in an existing service facility, before and after the application of methodology proposed. An individual truck trip is used to collect the commodities separately before the application of the methodology.

Table 7.2 shows the approximate cost and time savings after the optimization. The cost savings is based on the calorific value of fuel used, i.e. combustion of one litre fuel release 9.6 KWh (based on the gross calorific value from the Digest of UK energy statistics 2005) and the time savings (considering 45 Km/liter as base).

Table 7.1 Energy conserved by the truck

<table>
<thead>
<tr>
<th>No of commodities picked (Nos)</th>
<th>Distance (km)</th>
<th>Energy use by the truck (kWh) per Week</th>
<th>Energy use by the truck (kWh) per Year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before</td>
<td>After</td>
<td>Before</td>
</tr>
<tr>
<td>24</td>
<td>195</td>
<td>58.27</td>
<td>187.2</td>
</tr>
<tr>
<td></td>
<td>(With 24</td>
<td>(With 6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>routes)</td>
<td>routes)</td>
<td></td>
</tr>
<tr>
<td>Total Energy conserved</td>
<td></td>
<td></td>
<td>131.2608</td>
</tr>
</tbody>
</table>
Table 7.2 Energy, Cost and Time savings

<table>
<thead>
<tr>
<th>Energy Saved (KWh)</th>
<th>Fuel used (litre) (@ 9.6 KWh / litre)</th>
<th>Cost savings (Rs) (@ Rs 48/litre)</th>
<th>Time savings (hrs) (@45 Km/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6300.518</td>
<td>656.304</td>
<td>31502.59</td>
<td>145.7778</td>
</tr>
</tbody>
</table>

In order to reduce the energy used by the truck trips, we used the proposed methodology. The model is solved with VRP SOLVER, V (1.3). This results a minimum of 6 routes with truck capacity 4, to pick up 24 no of commodities with a total distance of 58.27 km, against 24 different routes with a distance of 195km.

**Fig. 7.2 Routes used before optimization**

The number of routes followed/used to pick up the returned commodities (multi-commodities) from the customer/disposer market before the application of the heuristics proposed is shown in Figure 7.2. Individual truck trips were followed to collect the returns before the application the heuristic procedure.

Optimal routes are obtained after the application of the proposed heuristics. The routes obtained are shown in Figure 7.3.
The optimal routes obtained to pick the returns (multi-commodities) after the optimization process was compared with the individual routes followed before the optimization. The comparison results of the routes are shown in Table 7.3.

### Table 7.3 Comparison of Routes

<table>
<thead>
<tr>
<th>Result</th>
<th>Before Optimization</th>
<th>After Optimization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Distance</td>
<td>195 Km</td>
<td>58.27 Km</td>
</tr>
<tr>
<td>Number of Routes</td>
<td>24</td>
<td>06</td>
</tr>
<tr>
<td>Truck Capacity</td>
<td>1 Commodities/trip</td>
<td>4 Commodities/trip</td>
</tr>
</tbody>
</table>

#### 7.6 Computational Results

The model was simulated with a real time data obtained from a service facility. The simulation involves the flow of returned commodities to the repair service facilities. The simulation results shows that the vehicle routing problem proposed along with the methodology for energy conservative measures, reduces the energy use by the trucks and the emission and noise of the trucks to a large extent.
7.7 Validation of the Model

In this work vehicle routing with energy conservative measures in Reverse Logistics Networking analyzed. The results obtained have been validated with the real time data from the organization under study.

7.8 Results and Discussion

In this work, we formulated a vehicle routing problem for solving the real logistic problem involved in a RL networking with multi-commodity flows. The model formulation has been done with the objectives of reducing the energy use by the trucks while transporting the commodities to existing service facilities and thereby reducing the emission and noise, which impact the environment greatly.

The vehicle routing heuristics optimized the routes to be followed to pick retuned multi-commodities; hence there is considerable reduction on the logistics cost, **Rs.31502.59** saved with improved customer’s satisfaction.

Energy conservation measures as suggested would further reduce the transportation time and it was found that, **145.7778 hrs** of time saved and operating cost of the repair service facilities while conserving the precious fuel.