Expanding Margins: Reclaiming Aviation Grade Lubrication Oils

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***Abstract*— The aviation industry is governed by very well defined maintenance philosophies. Concurrently, strictly complaint technical procedures/ practices are hallmark of this industry. Therefore, very high quality and costly lubricants are required to support aircraft operations. Oil is used primarily as lubricants, power transmitters and coolants in aircrafts. Further, due to flight safety considerations, the change-over period for oils are very well defined and strictly complied.**

Reclamation/ recycling of used oil are an accepted fact worldwide in automobile industry. The reverse supply chain starts at the repair depots/ workshops and ensure safe collection/ transportation of used oil back to a central warehouse/ reclamation plant where it is re-processed.

In the aviation sector, there is a value proposition which can generate ancillary revenue, by reclaiming the used/ waste oil. It is estimated that the Scheduled Domestic carriers consumed (or re-charged) over one lakh liters of lubricant (hydraulic and engine) oil for 9.35 lakh hrs of cumulative flying done in year 2013. The consumption pattern of engine oil/ hydraulic oil can be estimated on flying hours basis. These figures can be used to project the recoverable quantities of oil at 75% efficiency using existing technologies.

This paper discusses this unique possibility by conceptualizing a reverse supply chain model for collection/ transportation of used aviation oil. Various technical procedures, relevant literature and various case studies on handling waste oil were reviewed to develop the basic framework for the Reverse Supply Chain model.

***Index Terms*— Ancillary revenue, Aviation, Oil Reclamation, Reverse Supply Chain Mode**

I. INTRODUCTION

1.1 Aviation oils are hydrocarbon fluids that are used in aircraft for its operation. They serve as power transmitters, lubricant, coolant, etc. These oils are derived from petroleum based feedstock which is naturally occurring and consists of complex mixtures of various other minerals. India is largely dependent on imported crude oil to meet its domestic requirement of aviation grade lubrication oils (India, 2009). It is either imported directly as branded product or supplied by Indian companies by blending imported additives to base-stock produced indigenously.

1.2 Engine Oil used in aero-engines and hydraulic oil used for power transmission gets contaminated during flying operations. The contaminants include undesirable oxidation products, degraded additives, sediments, worn out metallic particles and condensed water vapour. This leads to decline in important physical and chemical properties of oil like viscosity, specific gravity, flash point and Ph value. These impurities remain suspended in oil until it is flushed out or drained off the system during scheduled servicing (Volkan PELİTLİ, 2014).

1.3 Technically, aviation oil must be replaced during scheduled servicing because of degradation/ decline in its quality and flight safety concerns. It is estimated that the Scheduled Domestic carriers purchased (or re-charged) over one lakh litres of lubricant (hydraulic and engine) oil for the 9.35 lakh hrs of cumulative flying done during the year 2013(DGCA, 2013). It is estimated that, during routine flying operations the aircraft consumes (burnt-out) about 8%-10% of engine oil and about 3%-5% of hydraulic oil. Further, about 5%-10% of total quantity is also lost during handling, transportation, and allied maintenance activities. Thus, about 75-80% of annual procurement is returned to store as waste oil. This used oil is later stored along-with other types of automotive oils and sold as scrap.

1.4 It is opined that, if all the drained out aviation oil is systematically collected and returned to store; atleast 75 -80% used oil can be reclaimed. A number of commercially viable methods for reclamation/ recycling waste oils are available across the country. These processes can be tailored to suite the strict aviation requirements and restore the physical/ chemical properties of oil (OG Kayode Sote, 2011)

II. RECLAMATION/ RECYCLING.

2.1 Reclamation is a process of removing impurities from waste oil so that it can be reused as base-stock for producing new lubricating oil. The process can prolong the life of natural oil resource which has not been burnt. According to US Environmental Protection Agency (EPA) reclaiming oil saves energy as well as produces fresh stocks of virgin oil (Managing Used Oil Advice for Small Businesses, November 1996).

- ✓ Reclamation of used oil takes only about one –third the energy required for refining crude oil to lubricant quality.
- ✓ It takes 42 gallons of crude oil, but only one gallon of used oil, to produce 2½ quart of new, high quality lubricant oil.
- ✓ The used oil from one oil change can contaminate 1 million gallons of fresh water—a years' supply for 50 people.
- ✓ One litre of unprocessed waste oil still contains about 9,300 KCals of heat energy if used as fuel.

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2.2 Reclamation/ recycling of used oil is an accepted fact in automobile industry worldwide. European and North American nations use recycled oil as base oil to meet atleast 40% of its domestic oil requirement. Very strict government regulations are in place for lifecycle management of oil for Industrial as well as Domestic users. For example 'British Columbia' recycles approximately 74.6% of its oil through strict regulations and public awareness programs (British Columbia Used Oil Management Association: Annual Report , 2013). As per UN Environment Program studies on oils, France collects about 78% of used oil, out of which 42% is re-refined. Whereas, Germany recovers 94%, with 41% reclaimed as base-stock (Prof. K. R. Chari, 2013). On the same scale, India has capacity to collect and process only 8 lakh KL of lubricant annually, which was about 25% of its consumption.

2.3 In India, due to lack of strict regulations, the oil recycling industry has not been able to mature as its European counterparts. Concurrently, no established logistic chain is in place for proper collection and resupplying oil to reclamation plants. Further, there exists a lack of general awareness amongst technicians, worker, and consumer about the requirement for proper disposal of used oil. This has lead to enormous revenue losses and environmental hazard. The reasons for this dismal collection and reclamation can be broadly listed as under:-

- ✓ Lack of public awareness.
- ✓ Poor enforcement of regulations.

III. Indian Context

3.1 During yr 2008-09 there was an exponential increase in cost of imported crude oil and concurrently there was a rise in demand of oil. The Ministry of Environment and Forest issued guidelines for recycling/ re-processing of selected group of wastes in yr 2010 which included used oil under Hazardous Waste Rules 2008 (MoEF). The Central Pollution Control Board also granted licenses to about 250 small/ medium recycles to process waste oil. Further, environmental considerations regarding the conservation of resources also boosted interest in recycling of used oil. In-spite of regulation, procedures, licences and rules the reclamation of lubricants in India has not matched up to world standards. Today, India is the 4th largest consumer of Oil after US, China and Japan, but importing much more oil than Japan in 2013. At daily consumption of oil was about 3500 thousand barrels.

3.2 The report on Waste Oils prepared by International Environmental Technology Centre, UNEP, India projects that Aviation Industry consumes atleast 10% of total Lubrication oil sold annually (Prof. K. R. Chari, 2013). Industry experts also suggest; that due to inherent maintenance standards in aviation, the collection efficiency in the sector could be about 90% (due to good handling and accounting) with re-generation factor upto 70% (due to low contamination). Therefore, aviation industry is alone capable of generating about 3.2 lakh KL of good quality waste oil. This waste oil can be reclaimed at much lesser cost if it is managed/ handled properly.

3.3 In India independent private collectors collect used oil from automotive service centres, industries, aircraft MROs, etc. These individuals, usually collects about 2000L of used oil daily and further sell it to bigger contractors. Some level of cleaning and segregation of oil takes place at this level. Heavy sediment oil waste is sold as 'fuel' to brick kilns and as 'lubricant' to small scale industrial fabricators. The bigger contractors fall under the category of organised sector. They are in direct contact with the oil-recycler. Most oil recyclers in India re-filter the used oil and sell it as heavy industry lubrication oil. Few recyclers also reprocess/ reclaim the waste oil to produce fresh base-stock. As against 32 lakh KL per annum consumption of lubrication oil (http://www.indexmundi.com/energy.aspx?country=in&product=other-petroleum&graph=production+consumption 2010), India today had only 8 lakh KL per annum of installed capacity for recycling in 2010.

3.4 Study of the industry practices in India brings out that there is an urgent need comprehensively review the management of lubricant oil by:-

- ✓ Increasing awareness and participation of aviation technician
- ✓ Enforcing regulations and
- ✓ Developing a reverse supply chain for transporting of used oils.

IV. Managing Used Oil.

4.1 Valuable outline on managing/ handling used oil for small businesses like fleet maintenance facilities/ MRO's, etc is given in US Environmental Protection Agency's (EPA's) code of federal Regulations, part 279. The agency further strongly advocates that it is very important to segregate oil at source as well as at drain-off point so as to ensure safe reclamation. It advices that used oil should not be mixed with any other waste. Mixed used oil becomes a hazardous waste. Handling/ re-refining/disposal of such oil requires a lengthy and costly process. Therefore, it should be ensured that used oil is segregated type-wise and batch-wise the moment it is drained after use.

4.2 The regulation of waste management in Europe and North America has fostered creation of processes and activities that ensured establishment of reverse logistics system (RLS) with strong fundaments. The formulation of concepts, tools and regulation process that has ensured better Life Cycle Management of Waste Lubricants and wide spread gains. The reverse logistics chain has also ensured development of specific knowledge about oil management, transportation, disposal and value adding skills that has improved the economic viability of the whole process.

4.3 In the Indian context, the maintenance activities in aviation industry are fairly well organised. As they are governed by strict procedural regulations enforced by organisations like DGCA, FAA and aircraft equipment manufacturers. Therefore, issues dictating waste management can be implemented with greater ease. The literacy level and general awareness of Aviation Technicians is much more than and other maintenance set-up. Therefore, the first two issues brought out at Para 3.4 above can be addressed comfortably if the higher level managers are taken onboard this program. The only issue that need greater attention is the setting up of a robust Reverse Supply Chain to ensure proper collection, safe transportation and its effective integration with the reclamation process. The reverse supply chain for aviation oils requires knowledge of collaborative re-processing systems; legal frameworks and environmental friendly technology. Thus, the chain will involve much more than the activity of merely transportation of waste from the MRO to reclamation plant. Finally, the reclamation will use technology to allow the reinsertion of reclaimed oil back into the manufacturing stage. For this a suggestive model is discussed in the succeeding paras.

V. Proposed Method

5.1 Since the ultimate aim of the research work is to extend the life of oil and reduce cost of purchase of fresh base stock oil by the nation at large, therefore, the **Life Cycle Analysis (LCA)** approach is deemed most appropriate to analyse the performance of suggested model. The conceptual framework to design and develop the method of analysis is described in the following steps:-

Step 1: Motivation for Developing the Chain:

Presently, the process of collection of waste oil is highly unorganised and loosely regulated in India. Thereby, resulting in low recovery ratios and poor valuation of waste produce. However, if a well harmonized Reverse Supply Chain is developed for exploiting the full potential of waste oil, better value preposition is expected. The tertiary financials gains to the stakeholders would be one of the motivations for implement the philosophy.

Step 2: Preliminary Market Analysis: Market data collection and analysis represent fundamental activities in business management. The data generates information both about the availability (volume, quality and reliability) of raw material (waste oil in this case) as well as about the market for its reprocessing and reinsertion into the supply chain as fresh base-stock. For this the following procedure is proposed:-
To estimate the annual quantities of aviation oils consumed by commercial airlines and project recoverable/ reusable quantities, the following formula is proposed:-
Waste Generated α Oil Purchased
Empirical Equation for Aviation oil

$$Q_w = \sum_{n=H}^{n=0} (Qf - (Cb1 + Ch1)Qf)$$

Where:-
Q_w Quantity of waste generated
Q_f Quantity of fresh oil purchased
C_b Co-efficient of burnt oil
C_h Co-efficient of handling losses
H Operating hours of Oil

Step 3. Acquisition of Knowledge and System characterization:
information collated the chain will be classified according to the following and will drive the design and implementation decisions:

- ✓ Volumes generated;
- ✓ Potential for recyclability of waste;
- ✓ Relative location of the MRO discharging recovered materials;
- ✓ Location and relative distance of the reclamation units

Step 4: Selection of Basic Framework (Reference Model):

The proposed reference model is based on the concept of LCA (Life Cycle Analysis) as it is most applicable to this scenario as per referred literature. The framework would consist of identifying and defining the roles of different nodes in the reverse logistics network. The responsibilities and activities of each node are identified, as per their role. They are listed below along with their performance indicators. In the final model, the one node may have many roles, and different nodes may also have the similar roles.

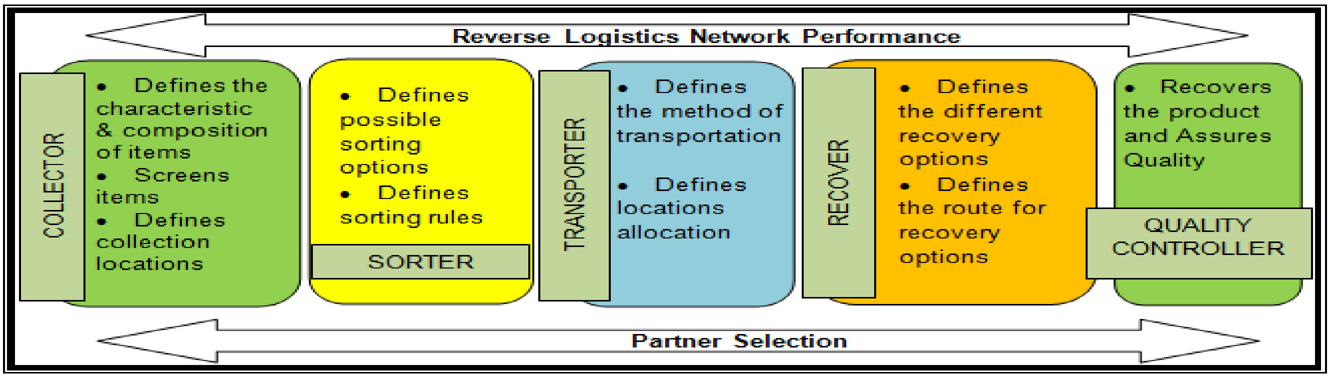
A The Collector: responsible for the gate-keeping and collection activities

B The Sorter: responsible for sorting different oil as per type

C The Transporter: responsible for transporting the oil to correct location as per type of oil and reclamation technology at plant.

D The Recover: responsible for recovery activities (reclamation)

E The Quality Controller: responsible to ensure maximum recovery and ensure quality of recovered base-stock.



The requirements of each node are case dependent. Most of them depend on the type of the product. The recycling processes for example differ based on the product type, whereas the general performance indicators are the same no matter the product type. Concerning the performance indicators, these can be:-

A. Total cost of the network including cost of transportation, facilities, purchasing, activities, and stock: This is the most used reverse logistics performance indicator.

B. Recycling rate: This indicator reflects the service level of the entire network. It reflects the percentage of recycled material for the product using the recovered reverse flow.

C. Life Cycle Assessment-related indicators: These indicators evaluates the environmental impact of the reverse logistics network. The most used life cycle assessment (LCA) indicators could be energy saving, carbon footprint of new product vs. reprocessed, energy-related indicators, chemicals used, toxic emissions, fresh water consumption, and use of power.

Step 5.Scenario Evaluation Technique:

The scenario evaluation is achieved by defining the reverse logistics network step by step, using decision criteria as per role. In this case, and for every role, the user will be asked to identify the best company based on decision criteria, which are identified in step 4. This option is based on the Analytical Hierarchy Process (AHP). AHP is the most used decision support system for engineering application. This technique relies on the expertise of the user in order to generate the weights of attributes. It is based on the comparison of pairs of options and criteria. It has found wide spread application in decision-making problems, involving multiple criteria in systems of many levels. The steps that need to be followed in this option are:-

(i) Feedback from potential partner on measured performance of decision criteria identified for each node.

(ii) Fill the criteria comparison matrix for all identified criteria

(iii) Choose a specific role of the reverse logistics network. The design may be made in a forward or backward manner. This means the allocation of partner per role may be realized by starting at the end of the network or at its beginning.

(iv) Choose a specific type of reverse flow.

(v) Identify all candidates (company/ facility/ supplier) for the chosen role.

(vi) Select the decision (selection) criteria of interest (from the pool of all available criteria).

(vii) Calculate the weights, using AHP.

(viii) Rank all candidates, using AHP.

(ix) Select the candidate ranked first.

(x) Allocate order quantities, choose transportation mode, and validate.

Steps 6: Result Analysis and Implementation:

After one or more scenarios are chosen, the different performance indicators are calculated. A comparison between the scenarios is provided. The evaluation of the reverse logistics network is achieved via life cycle assessment software (SimaPro 8.0.4). After the life cycle assessment of the different reverse logistics scenarios is received from the LCA software, a full analysis combing this assessment and the one achieved via the transportation model (total cost of the network, quantity of recycled material, etc.) will be provided to the user. A comparison of all created reverse logistics scenarios will also be shared with the user. The AHP method is reused at this stage to identify the best-fitting reverse logistics network.

5.2 The final layout of the transportation model would map each type of waste oil against the identified reclamation plant. The location of collection points and allocated qualities would also be identified. This would then be collaborated with inputs on transportation cost, reclamation cost, etc against revenue earned by sale of re-processed base-stock oil. The cost benefits accrued would then be compared to the revenue generated by the existing process/ chain. This would bring out the value preposition of this model.

VI. Conclusion

Used oil management in India is an important topic that has not received sufficient attention till date. Though recycling and reclamation has been permitted by the Government, it has not received the impetus that it deserves. The recycling sector is still informally organised and insufficiently supported by common citizens' laws and regulations. Reclaiming used oil can conserve oil resource, ease nation's energy crisis and provide a source of ancillary income to aviation industry. The process can also reduce the carbon footprint of the industry and help produce a greener environment. In order to enhance reclamation, participation of all personal across all hierarchy is solicited. A well established Reverse Supply Chain will ensure minimum wastage of waste aviation oil.

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