

**METHODS TO DETERMINE THE BEST
PRACTICES OF AUTOMOTIVE FLUIDS
DRAINAGE IN END-OF-LIFE VEHICLES (ELVs)**

A

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BONAFIDE CERTIFICATE




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ABSTRACT

Automotive Industry, globally, as well in India, is one of the key sectors of the economy. The automotive industry in India is growing at a compounded annual growth rate of over 10%. As India's GDP grows, economic activity will increase and vehicle populations will grow even faster. With the rapid and exponential growth of industrial production in India, the issue of disposal of automobiles at the end of useful life is becoming increasingly important. After a product's life cycle has ended, there are number of recovery options available such as reusing the parts, remanufacturing, and material recycling. Major car manufacturers worldwide have adopted common databases to facilitate dismantling and analysing recyclability of materials. The problem is yet to attract serious attention in India with needs to formulate policies, systems and regulations to deal with end-of life vehicles (ELVs).

According to the data obtained from Society of Indian Automotive Manufacturers, the vehicles produced in eighties are certainly due for scrapping owing to low fuel efficiency and excessive pollution. But, these vehicles are still on the roads and pose a major concern. India does not have any infrastructure and organized system for collection, dismantling, shredding and processing auto scrap. This is an issue, which calls for immediate and careful attention from the government and all stakeholders, before it burgeons into a major national problem.

The literature review attempts to record in brief, the findings from literature on various aspects of fluids drainage procedures in the automotive industry. The interfacing issues, current practices, limitations of existing methods, properties of the oils drained out and their harmful effects if not properly disposed off have been discussed. The end-of-life vehicles are comprised of approximately 9% plastics, 73 % ferrous and non-ferrous metals, 5% fluids and 13% other materials by weight.

In India, sufficient work has not been done on identifying the reasons why automotive recycling has not been able to embed their footprints even after half a century of inception. A simple look at automotive recycling of the vehicles data reveals the fact that as compared to developed countries like US, the methodological advancements in India are fraction of their technology. Technological procedures that comprise of the standardized methodology for the processing of end-of-life vehicles have not attracted much attention and not much work has been done in this area. Thus, the prime concern of this research is to identify the best practices for the automotive fluids drainage from ELVs that can minimize environment pollution, save excessive fuel usage and improve the health and safety of workers.

The technology presently in use for removal of fluids has been studied. The manual and semi-automatic fluid drainage process of petrol/diesel, engine oil, coolant and gear oil have been studied to determine their step-to-step removal process from a vehicle through online survey, visiting the service centers in India and recycling facilities in Canada. A well-structured comprehensive questionnaire has been designed which seeks on identifying the various input parameters required for the drainage of fluids that ultimately aggravate the outcomes on the output parameters. Both descriptive and empirical analysis has been conducted to identify the relationship between the key input and output parameters.

Cronbach's Alpha coefficient was calculated for each of the fluids studied during the research study individually to validate the questionnaire. The Pearson Partial Correlation between two variables, after controlling for variables in the partial statement has been performed to illustrate the correlation between input and output factors. For a closer examination of relationships between individual dimensions of dependent variable with the independent variables, the multinomial logistic regression analysis has been carried out. The statistical findings have been considered during the design of the proposed drainage method for the ELVs.

In addition, Industrial Engineering tools have been applied to determine the root cause of the problem and provide recommendations for the current drainage process. Flow process charts have been prepared for different facilities visited while categorizing them into three different facility types depending on the drainage procedure. Failure Mode Effect and Analysis (FMEA) tool was used to analyze the impact of environment and ergonomic issues of the current practices for petrol/diesel drainage that facilities are following.

Furthermore, the Pugh analysis compared the current facility types to the proposed facility type, (F4, datum) to validate the proposed solution. The findings from the statistical and industrial analysis have been combined and a standardized drainage method for the drainage of automotive fluids been proposed by preparing a computer-aided design (CAD) model. Lastly, the break-even analysis depicts the minimum number of days required by the company to perform the drainage process using the proposed drainage method such that the total revenue generated overcomes the total costs.

In conclusion, an innovative process has been proposed providing hygienic work conditions along with processing of higher volumes of vehicles and having proper disposal method for the various fluids drained out from end-of-life vehicles. Application of research results for proliferation of automotive recycling at base level has been highlighted in Indian context.

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CHAPTER 1. INTRODUCTION

1.1 General

Automotive Industry, globally, as well in India, is one of the key sectors of the economy. India is emerging as one of the world's fastest growing passenger car market and second largest two wheeler manufacturer. According to the Indian statistics, the automotive industry is producing about 13 lakhs passenger vehicles per annum. The production of passenger cars in India has grown more than threefold over the last decade. India is primarily a small-car market, with small cars constituting around 75 per cent of the total production.

With the rapid and exponential growth of industrial production in India, the issue of disposal of automobiles at the end of useful life is becoming increasingly important. The vehicles at the end of their useful life, can follow the universal progressive system of reuse, remanufacture and finally recycle. The element of recyclability, consisting of ease of dismantling, use of recyclable materials, elimination of toxic substances etc. has to be built in the basic design and production systems. The methods used for recycling have to consider environmental protection, industrial safety and social considerations as seen in figure 1.1.

Major car manufacturers worldwide have adopted common databases to facilitate dismantling and analysing recyclability of materials. The problem is yet to attract serious attention in India with needs to formulate policies, systems and regulations to deal with end of life vehicles (ELV).

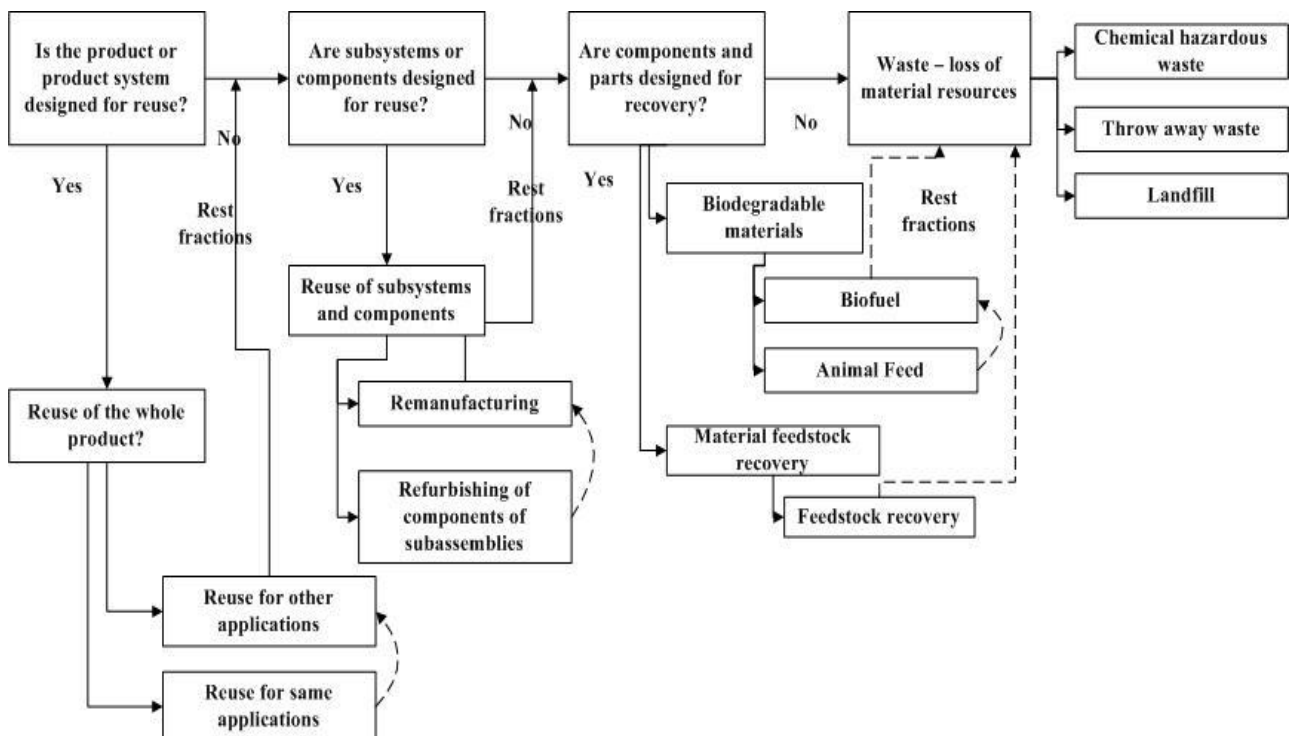


Figure 1.1: Recycling process of automotive industry

1.2 End-of-Life Vehicle (ELV)

The end-of-life phase is seen in every product life cycle that is manufactured. The end-of-life phase is the least studied phases of the vehicle life- cycle. The processes currently in practice for ELV's are principally dismantling and shredding. They are typically perceived as distinct processes, and each has distinct challenges. Typically, end-of-life vehicles are initially dismantled, followed by shredding process. After a product's life cycle has ended, there are number of recovery options available such as reusing the parts, remanufacturing, material recycling etc. In order to choose one of these recovery methods it is entirely based upon the quality of the parts/ components and the economic benefits of choosing that part.

In our report, the focus is on automotive recycling process of an End-of-Life Vehicle. An End-of-Life Vehicle (ELV) is a vehicle that has reached the end of its life and which can be processed for recycling or remanufacturing its parts by the automotive recyclers. Recycling has become an important part of preserving the environment and in the automotive industry, recyclers ensure that all reusable parts are removed from the ELVs and stored in a safe manner. In addition, the recycled material accounts for 15-20 percent in weight of the total mass of plastic materials used in the vehicles, which saves our natural resources and introduces closed-loop recycling process. The end-of-life vehicle process involves three major stages, which maximizes the amount of material that can be reused.

The first step involves removal of all fluids from the vehicle i.e. petrol/diesel, engine oil, coolant, gear oil etc. since, these fluids can be harmful for the work environment they are handled properly in a safe manner by using special equipment and following certain regulations. After the fluids have been drained out parts such as fuel tank, battery, tires and mercury switches are also removed from the vehicle. The second step involves removal of main parts from the car, which can be reused or remanufactured depending on their condition. The parts removed from the vehicle are tagged by a computerized inventory system and stored in the warehouse to be sold to a customer in future. Lastly, after all the parts and fluids have been removed from the vehicle it is crushed and stored in a yard. After a batch of vehicles are stacked in the yard they are sent to the shredder for further processing of the plastic and metal parts of the vehicle. The ferrous and non-ferrous metals are separated and reused to make new vehicles and other products. Hence, the vehicle continues its life cycle process.

1.3 Indian Perception of ELVs

In India, cars are driven for 15-20 years until they can no longer be cajoled into life often land at scrap dealers, to be dismantled and their innards reused with little regard of the environment. These vehicles are technically named as End-of-Life Vehicles (ELVs).

As previously mentioned, the materials recovered from ELVs follow a hierarchy of four 'R's which are as follows:

- i. **Reuse** – parts which can be removed and reused (mostly from vehicles involved in accidents)
- ii. **Remanufacture** – items like electric motors, alternators, starters which can be remanufactured from recovered parts.
- iii. **Recycle** – majority of items and parts which can be recycled to generate useful raw material and feedstock.
- iv. **Residue** – left over Automotive Shredder Residue (ASR) to be dumped in landfills.

The recycling of metals from end-of-life vehicles has environmental benefits because the ecological footprint of recycled commodities (especially metals) is smaller than unused commodities. Metals such as lead from lead-acid batteries, tire weights and battery terminals, iron, copper in the wiring, aluminum from wheels and engine components and rare earth metals in the catalyst converter are the primary metals recovered from vehicles.

The recycling of rubber from tires is also important. The recycling of rubber can be used to produce a variety of products such as athletic tracks, mats and asphalt.

Plastic recycling from end-of-life vehicles is limited because of the low price of recycled plastic and the composite nature of plastics used in vehicles – composite plastics are harder to recycle because of the mixture of plastic types.

The parts stored in a warehouse at a local scrapyards can be seen in Appendix - I. The parts include such as engines, fuel tanks, alternators, and electric wires etc. of different make and model of the cars. However, no record of the parts removed from the cars is maintained by the owner of the warehouse; thus resulting in time-consuming process when the customer requires a specific part. The parts are warehoused considering the fact that; they might be sold in future to a consumer or shredder depending upon the circumstances.

Moreover, the data in Table 1.1: Indian Automobile Population (SIAM Data) illustrates that the vehicles produced in the eighties are certainly due for scrapping owing to low fuel efficiency and excessive pollution. But, these vehicles are still on the roads and a major concern.

In addition, it has also been observed that the Indian auto industry has witnessed phenomenal growth i.e. approximately 13 times since 1980's.

Table 1.1: Indian Automobile Population (SIAM Data)

Year	Production during year (Thousands)	Year-end population (Millions)
1980-81	580	5.4
1981-86	1,400	10.6
1986-91	2,340	21.4
1995-96	3,340	33.6
2001-2004	4,960	55.0
2004-2005	8,170	67.0

Over seventeen million vehicles were added to the vehicle fleet last year, including nearly two million cars and seven million plus two wheelers. The industry is growing at a compounded annual growth rate of over 10%. As India's GDP grows, economic activity will increase and vehicle populations will grow even faster.

Presently, only 1.5-2.5% of vehicle population is retired annually in India, mostly because of natural attrition, accidents or Government norms as per National Automotive Testing & R&D Infrastructure Project (NATRiP) statistics.

According to a report by Capt. N.S. Mohan Ram, Chairman of Indian Automotive Recycling Group, India has no formal regulations regarding recyclability and disposal of ELVs. India does not have any infrastructure and organized system for collection, dismantling, shredding and processing auto scrap. In addition, the report also mentioned that auto industry is on a fast growth track over the last decade and the situation will change dramatically when vehicles currently being produced come in for scrapping.

The unhygienic conditions of work and the disposal of the used oil at Indian facilities pose a major environmental concern as seen in Appendix – II.

1.4 Non-Indian Perception of ELVs

In-order to compare the existing automotive fluids drainage procedure information was collected outside India in Ontario, Canada through OARA. Ontario Automotive Recyclers Association (OARA), is the representative body of automotive recyclers in the province of Ontario since 1992. OARA ensures that all auto recyclers in Ontario are kept abreast of the current industry updates and trends, government legislatives and salvage regulations. OARA partners with other automotive associations and government working groups to address best practices and future solutions regarding scrap tires, waste oil (engine oil, gear oil, brake fluid etc.), other fluids (coolant, windshield washer fluid etc.), mercury switches, and wrecked or salvage vehicle body. OARA work towards bringing positive changes that will result in both economic and environmental benefits.

The Government of Canada and OARA coordinately try to implement new auto recycling programs and promote them through advertisement, annual conventions etc. The programs currently promoted are: Go Green Parts and Retire Your Ride. Go Green Parts program are ultimate environmental choice for today's world. The program allows the dismantlers to save maximum amount of parts from an ELV, which saves an estimated 80 million barrels of oil annually, required to produce new replacement parts. Not only does it keep a flood of dangerous toxins from being released into the ground and water, it also prevents unnecessary use of valuable landfill. Retire Your Ride program has been designed to enable people to get their high-polluting cars off the road and in return be rewarded for it. This program would improve the air quality and keep the environment safe. The rewards could be in the form of cash back, rebate towards the purchase of a newer vehicle etc. These programs certainly enlighten the knowledge of people about their ELVs and its environmental sequences if proper procedures are not followed.

According to the statistics from Ontario, there are more than 400,000 vehicles taken off the road every year and, there is a great potential for operating fluids and other hazardous components that can contaminate the environment. (Recycling Council of Ontario, 1999) In-order to overcome this problem, Canadian government has implemented strict regulations for the recycling industry to use appropriate equipment and follow environmentally friendly procedures to save the world from destruction.

To illustrate an organized method of dismantling, storage of the fluids and warehousing of the parts can be seen in Appendix – III.

1.5 Change through Innovation

Innovation is the engine of change and considering today's competitive environment, resisting change is dangerous. Change, while it brings uncertainty and risk, also creates opportunity (Ahmed, 1998) for innovation. Innovation helps the organization to deal with the turbulence of external environment, and, therefore, is one of the key drivers of long-term success in business, particularly, in dynamic markets.

Innovation is described as a pervasive attitude that allows business to see beyond the present and create the future. There is no escape from the reality that, organizations must continuously innovate in order to survive, especially in this era of rapidly changing market conditions. Innovation results in generation and implementation of new or improved processes, services, products, production methods or single actions aimed at increasing the competitiveness of an enterprise (Lei et al., 1999).

Considering the present situation of recycling in India, there is a need for change in respect of recycling and recovering materials from these vehicles, which are at the end of their useful life. It is mandatory in developed nations to recycle the vehicles after the end of their lifespan. However, in India there are no such regulations to deal with old and non-usable automobiles. Mostly, such vehicles are sold as scrap where auto parts are dismantled and sold separately. After that, the metal parts are recovered. However, due to the lack of modern techniques, the process is highly polluting and has low rate of recovery. This is an issue, which calls for immediate and careful attention from the government and all stakeholders, before it burgeons into a major national problem.

1.6 Innovation for Technology Development

Since it is difficult in practice to separate technology from the organization and the employees, an open definition of technology is chosen in academic writings. The word 'technology' comes from two Greek words '*Techne*' and '*Logos*'. '*Techne*' means the skill or craft needed to make something and '*Logos*' means discussion or knowledge of something. Technology is defined as the practical knowledge, know-how, skill and artifacts that can be used to develop a new product or service and/or a new productivity/delivery system (Moriarty et al., 1990). It is the scientific, engineering, and managerial knowledge which makes possible the conception, design, development, production, and distribution of goods and services.

Hence, technological change is the social and economic process through which an invention becomes a novel technology, and then diffuses within an industry.

Global competition and liberalization of industrial policies has reinforced the need for technology upgradation to attain international level of competitiveness and to be able to offer contemporary levels of technology. As a result, the technology presently in use for removal of fluids in India is lacking advancement and technology upgradation would certainly be beneficial and if the problem is tackled as a national challenge, Automobile Recycling can:

- i. Minimize environmental pollution,
- ii. Save excessive fuel usage, and
- iii. Improve the health and safety of workers.

The additional benefits of Automobile Recycling in India are:

- i. Disposal of 25,000 tonnes of auto residue,
- ii. Recovery of 1.5 million tonnes of steel scrap,
- iii. 180,000 tonnes of aluminium scrap,
- iv. 75,000 tonnes each of plastic and rubber, and
- v. Automotive Shredder Residue (ASR) to be disposed-off in landfills would be about 2,50,000 tones, which would strain land availability.

1.7 Research Problem

Successful innovation occurs when an invention, related to a product, service or a process in some part of the organization's value chain, is joined with a business design, which in turn is implemented with discipline and skills through innovation management. Successful innovation management requires developing a strategic approach to innovation. The present research work has been carried out for the automotive recycling sector in India.

The current problem of automotive recycling in India is at a crucial stage. Scrap dealers dismantle the vehicle; take away the bearings, electrical parts, body parts, to recycle. The whole system is very unhygienic and can handle only low volumes. Moreover, there are approximately millions of vehicles taken off the road every year in India, there is a great danger for operating fluids and other hazardous components to be released into the environment. The manual fluid drainage process of petrol/diesel, engine oil, coolant and gear oil results have been studied to determine their step-to-step removal process. The drainage of petrol/diesel results in the development of fuel vapors that pose serious health issues.

Fluids like petrol/diesel, engine oil, transmission oil and coolant can be detrimental to ground and water environment. Fluids must be contained or disposed of prior to the further processing of the ELVs. Even storing a vehicle in an auto garage or junkyard can itself be a threat since the gradual corrosion will cause the tanks, reservoirs and pipes to leak. Although, it is beneficial to store all the oils and other fluids separately since many of them can be recycled, it is time consuming and inconvenient to drain and store each fluid and oil in its own separate container.

Therefore, the above mentioned method enlightens us the necessity for the implementation of new techniques to be carried out in automotive recycling industry for attaining the best results. In order, to illustrate the benefits of this method, a comparative analysis of the existing Indian system with American system has been carried out. Hence, an innovative process has been proposed providing hygienic work conditions along with processing of higher volumes of vehicles and having proper storage facilities for the used oils.

The objective of this project is to find best practices for automotive fluids drainage, which are to:

- i. Minimize environmental pollution,
- ii. Consider health and safety of the workers,
- iii. Time-efficient process, and
- iv. Cost-effective process.

1.8 Organization of the Thesis

The write up of the thesis is divided into six chapters as discussed as follows. The overall structure of thesis is presented in Figure 7.

- **Chapter I** justifies the need for present work. It underlines the aim of research problem and covers the organization of thesis.
- **Chapter II** reviews in detail the previous studies in the field to identify the factors which facilitate technological improvements in automotive industry. It identifies the key inputs and outputs issues affecting the research problem. The chapter identifies the main limitation in the existing academic writings.
- **Chapter III** introduces overall design of the study. It explains the methodology carried out for the research work. The details of the work done in each phase of research, the tools and techniques used have been presented.
- **Chapter IV** presents the results of Indian and Non-Indian automotive facilities visited for the purpose of data collection regarding the automotive fluids drainage processes. In addition, results of the online survey have also been presented. Statistical analysis along with industrial engineering tools has been carried out to assess the current process and to determine the shortcomings that can be implemented in the proposed drainage process.
- **Chapter V** presents a synthesis of learning issues and outcomes of plant visits and survey through a decision matrix and break even analysis for the proposed drainage process in the automotive recycling industry.
- **Chapter VI** covers the summary of research work, its results, conclusions, and the recommendations. The limitations along with the scope of future work have also been covered in subsequent sections of this chapter.

1.9 Concluding Remarks

In the present dynamic world, ‘change’ is the only permanent thing. The present research study has been carried out to analyse the various technological developments of automobile industry in India and Canada through indigenous research initiatives. Even though there have been limitations of time and resources, but an attempt has been made to make this study exhaustive, intensive and as broad as possible.

An extensive review of literature is the first logical phase in a research effort and the next chapter is devoted to the same.

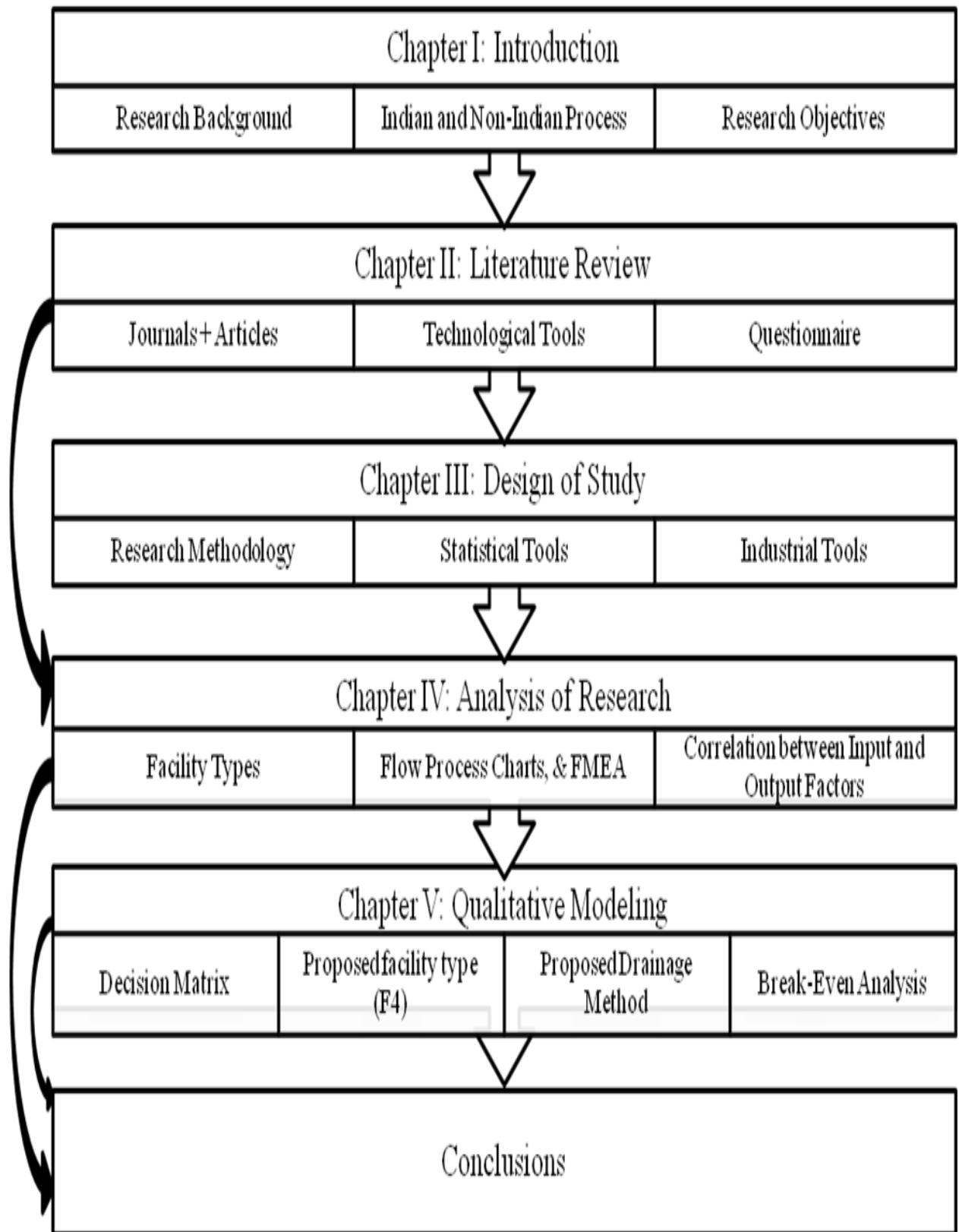


Figure 1.2: Thesis Structure

CHAPTER 2. LITERATURE REVIEW

2.1 Introduction

The results of research turn out to be more useful after a proper literature review and analysis has been carried out for the research area being studied. This chapter attempts to record in brief, the findings from literature on various aspects of fluids drainage procedures in the automotive industry. A methodical review of the concepts, technology in use for the drainage in India and Canada and the disposal issues of the fluids have been carried out. The interfacing issues, current practices, limitations of existing methods, properties of the oils drained out and their harmful effects if not properly disposed off have also been mentioned in this chapter.

2.2 Need for Technology Development

In today's competitive industrial environment, global competition is forcing industries and businesses to continuously seek ways to improve their products and services. The manufacturing units are pressurized to adapt to new technologies and external threats requires resourcefulness, creativity and innovation. Therefore, the decision to innovate a new process in the vehicle manufacturing must be supported by actions that create an environment in which people are comfortable with new innovation that they created. Enormous research has taken place to explain why certain industries have more innovative tools and equipment's than others. The study presents a detailed analysis of various factors and issues affecting technology development and its significance in affecting improvements.

2.3 End-of-Life Vehicle

From an end-of-life perspective – recycled or abandoned vehicles are considered permanently retired and, as such, are considered “end-of-life vehicles”. As mentioned by [Staudinger, 2001], automobile owners permanently retire their vehicles for a variety of reasons such as:

- Loss of structural/mechanical integrity from corrosion or an accident,
- Poor reliability of parts and components, and
- Degraded performance.

The decision to permanently retire a vehicle poses a challenging resource optimization problem from both an environmental and economic perspective. Even though considering, investment of additional parts and components to an old vehicle would extend the life of the vehicle, but the environmental performance of an old vehicle in terms of fuel economy and emissions is worse than

a newer vehicle. Considering this aspect of end-of-life vehicles this topic has been chosen as a research study to determine the different drainage procedures for automotive fluids and study in depth the different methods. This area of research has not been studied in such a detail earlier.

2.4 Vehicle Recycling Process in India

According to Sharma, Director of NATRiP [NATRiP, 2009], only 1.5-2.5% of vehicle population is going off the road annually in India – mostly because of natural attrition, accidents or Government norms. In the recycling process, multiple agencies are involved: vehicle manufacturers, dismantlers, shredders, metal processors, rubber and plastic processors, vehicle owners, central and state government agencies, local government and the last owner of the vehicle.

The procedure presently being followed has resulted in low productivity, ground water, surrounding contamination, and low material recovery percentage. Moreover, the vehicle dismantling and shredding industry is unorganized, the current practices of treatment, and disposal of environmental waste is a serious threat to environment.

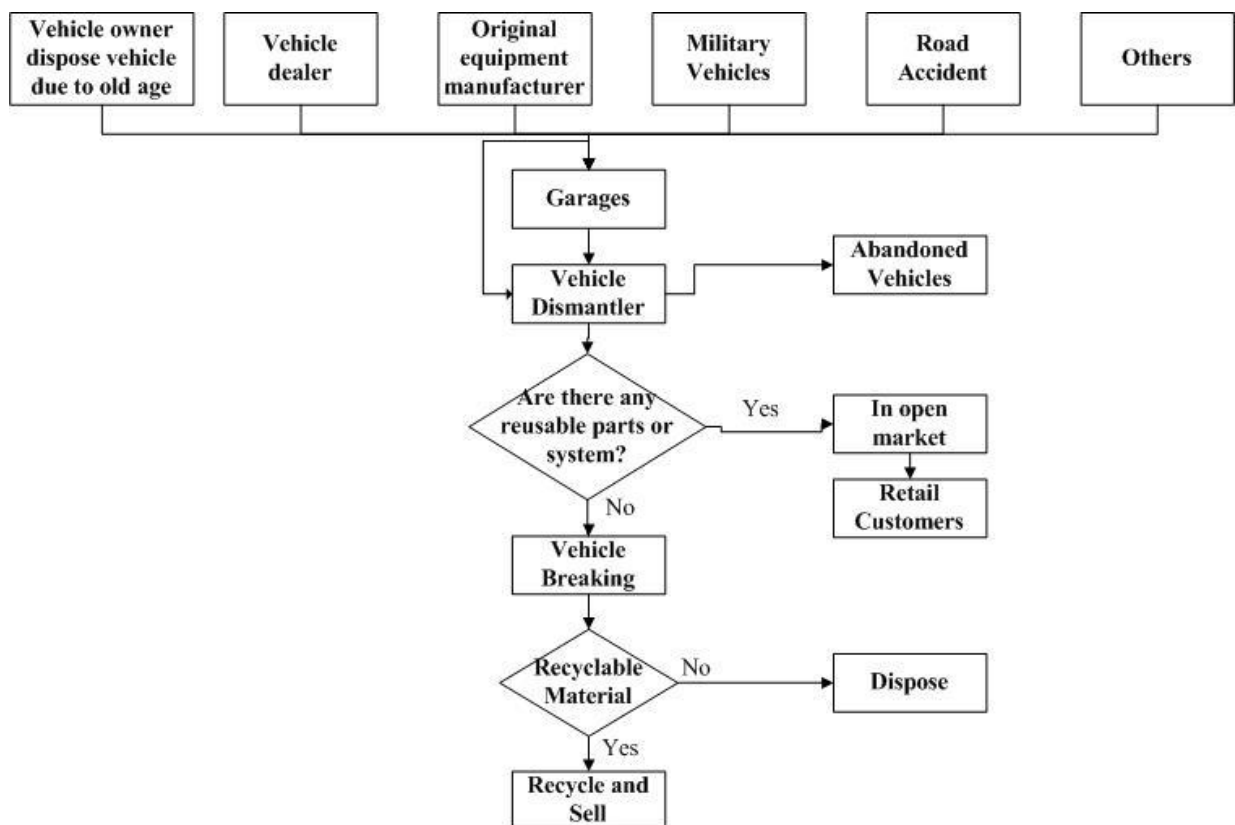


Figure 2.1: Current Vehicle Recycling Process in India

The figure 2.1 illustrates the overall vehicle recycling process presently being followed in India. It briefs out the steps performed by the scrapyards after the vehicle has reached its end stage either due to an accident or due to its end-of-life.



Figure 2.2: Parts removed after the vehicle has been dismantled

The Figure 2.2 depicts the scattered re-usable parts that have been recovered from an ELV by a scrap-dealer. Moreover, they pose a threat to the environment as well as to the health and safety of the workers.

2.5 Dismantling Process of ELVs in North America

Once an ELV arrives at the auto-recycling yard in North America, the vehicle must be stored on an impermeable surface, with sealed drainage until it has been de-polluted. This makes sure that any fluids leaking out are entrapped and cannot contaminate the surrounding area. After de-pollution, the vehicle can then go into the main yard. The broad process flow for dismantling vehicles is as below: [Department for Environment Food and Rural Affairs, 2011]

1. The vehicle to be scrapped is driven over to the window of an administrative office with destruction certificates, vehicle logbook and other statutory documentation. The dismantling agency will verify that the transaction is legal and then issue the necessary certificate to the disposer of the vehicle.
2. The dismantling unit should preferably have the dismantling manual for the particular make and model of the vehicle provided by the manufacturer. (Many manuals are available in company websites.) This will facilitate dismantling operations.
3. Remove batteries and later the battery boxes and store separately to be returned to the appropriate authority for recycling.

4. Remove next potentially explosive systems like air bags and seat belts using certified/trained people and store in a safe place.
5. Next drain different fluids separately in suitably lined containers like small tanks, barrels etc. Drain Petrol/Diesel, Diesel, different oils like gear oil, differential oils, different coolants like radiator coolant, brake fluids, antifreeze and refrigerants separately in labeled separate containers and disposed-off separately.
6. Remove and segregate hazardous and toxic materials such as Mercury. Fluorescent lamps, some switches, gas discharge lamps etc. contain mercury and cadmium.
7. Next remove tires, tubes and other rubber parts.
8. Plastic parts forming the external trim like fenders are removed next and labeled separately PP, ABS etc.
9. Remove glass items like windshields, windows and other glass parts and store separately.
10. Remove the internal trim segregating different materials like wood, resin, paper, cardboard, paperboard etc.
11. Remove brake discs, drums and linings. These are recyclable. Any asbestos bearing material is to be segregated.
12. Remove electrical fittings, motors, alternators, starters, etc, segregate and store them separately.
13. Remove and separately store, wiring harnesses should be for recovery of copper and prevent mixing up with steel parts.
14. Next, remove electronic items like printed circuit board (PCB), engine control unit (ECU).
15. Remove Aluminum parts and store separately for recycling.
16. Remove serviceable loose metal items like hubcaps etc.
17. Remove serviceable repairable engine parts.
18. Remove all plastic parts, rubber hoses etc. from the engine.

After following the above-mentioned dismantling steps, the worker assigns a 'clean chit' to the vehicle for shredding process.

Figure 2.3 shown below guides the worker about the detailed process steps for the processing of ELVs.

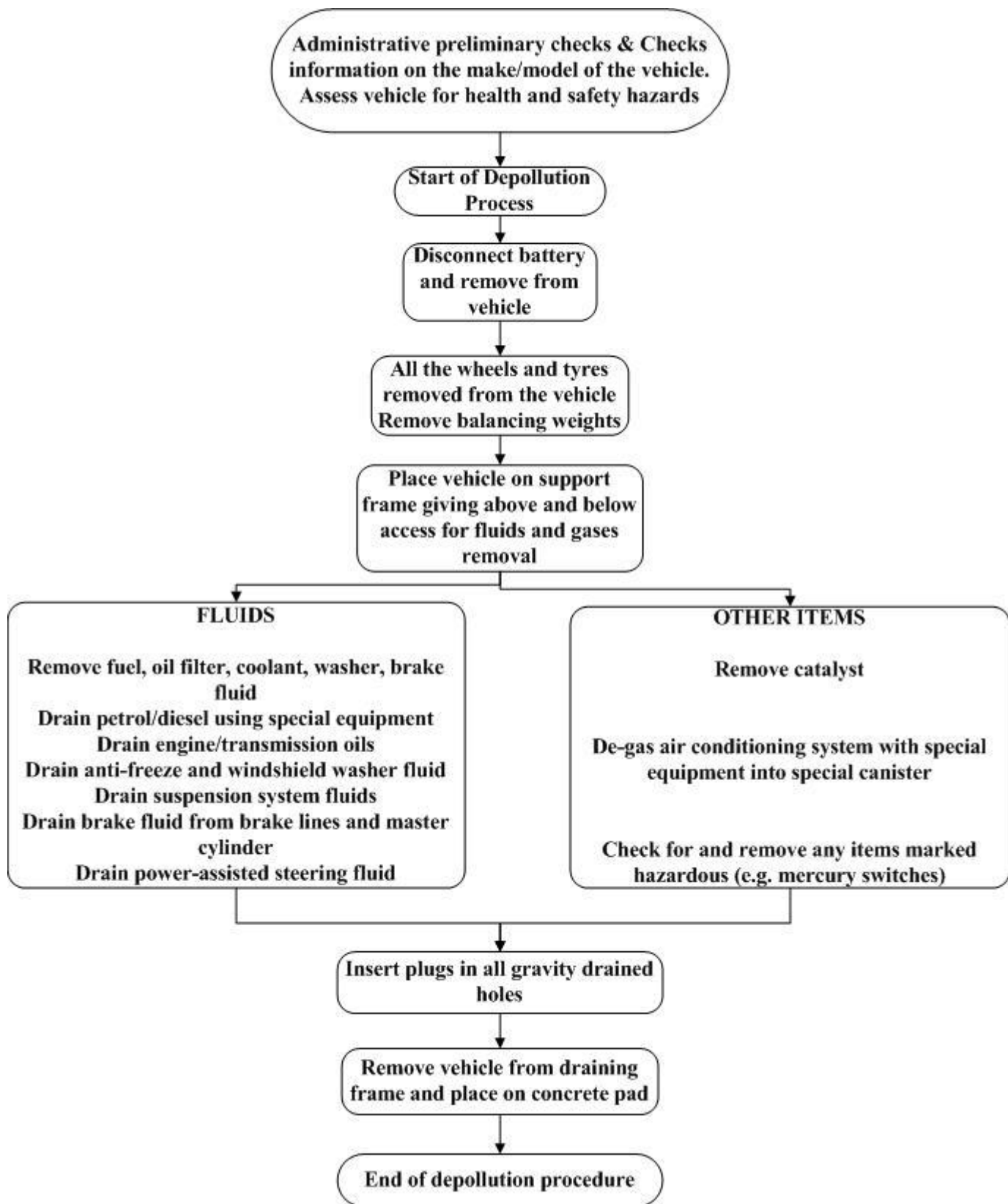


Figure 2.3: Process Flow Diagram for ELVs

Taking into consideration the health and safety of the worker, the vehicle must be placed on a support frame or lifting device, to allow easy access below the vehicle, before a number of these operations can be operated. It is preferable that the device should be adjustable to suit the height of the operator. Although access to the underneath of a vehicle could be provided by placing it above

a pit, there are health and safety issues with this approach, particularly with regard to possible buildup of fuel vapor in the pit during the depollution process. Consequently, the vehicle must be placed on a support frame, which enables easy access to the underside of the vehicle at the ground level. The depollution activities should be conducted using equipment that has been specifically designed for carrying out the process. It not only ensures safety but also makes the process time efficient and environmentally friendly.

2.6 End-of-Life Vehicle Management

According to the registration and sales data in US from 1989 to 1998, [Staudinger, 2001] showed that, on average, 6% of all the registered vehicles used in US are retired annually.

In 2005, approximately 18.5 million motor vehicles were registered in Canada according to Statistics Canada. The table illustrating the motor vehicles registered from 1986-2005 in Canada can be seen in Appendix I [Statistics Canada, 1999]. It can be estimated that the number of vehicles retired in Canada annually, will approximate U.S. vehicle retirement rate i.e. 6% of all registered vehicles in Canada which results in 1.2 million retired vehicles annually in Canada. Therefore, keeping in mind the changing trend of new vehicles produced over time it has certainly affected the time period for the retirement of the old vehicles. The estimated median life expectancy of a vehicle is 15 to 20 years ago.

This estimation has helped to determine the future of ELV management, being that the vehicles produced today will be prevailing ELVs 10 to 20 years down the road.

The end-of-life vehicles is comprised of approximately 9% plastics, 73 % ferrous and non-ferrous metals, 5% fluids and 13% other materials by weight.

The number of ELVs generated yearly depends on various factors including:

- General economic conditions,
- Overall vehicle accident rates, and
- General reliability of prevalent older-model vehicles.

A mathematical equation to determine the number of ELVs generated in a year is as follows: [Staudinger, 2001]

Estimated Number of Vehicles Retired From Use per Year =

$$\begin{aligned} & \text{(Number of Vehicles Registered at the Beginning of the Year)} + \\ & \text{(Number of Brand New Vehicles Registered During the Year)} - \\ & \text{(Number of Vehicles Registered at the End of the Year)} \end{aligned}$$

However, no such statistics data could be obtained in India to perform the above calculations.

The table 2.1 shown below estimates the vehicles retired for the period of 1990 to 1996 in U.S. [Staudinger, 2001]

Table 2.1: Estimated Motor Vehicles Retired from Use As Cited by AAMA

Year Ending 6/30:	Retirement Rate [million vehicles/yr]		
	Passenger Cars	Trucks & Buses	Total
1990	8.9	2.2	11.1
1991	8.6	2.3	10.9
1992	11.2	1.6	12.8
1993	7.4	1.0	8.4
1994	7.8	4.6	12.4
1995	7.4	2.9	10.3
1996	7.5	3.3	10.8
Average (90-96)	8.4	2.6	11.0

Thus, in estimating the vehicle retirement figures, for cars, use of the overall average 8.4 million per year, as cited in Table 2.1 – seems appropriate for research study purposes. Indeed, as detailed above, in essence the face of current ELVs largely reflects the prevailing mix of new vehicles produced 10 to 20 years ago.

Generally, ELVs in North America are processed by dismantling, then shredding, followed by separation of the low-density, non-metallic materials from the higher-density, metal-dominant fraction. The recovered ferrous and non-ferrous metals are recycled. The ferrous metals are recycled as alternative feedstock for steel mills. The non-ferrous metal fraction requires additional processing and treatment to separate the materials into individual metal fractions.

The table 2.2 provides an overall summary of ELV – related estimated mass flows in US considering the following facts:

- ELVs recycled are 13.5 million,
- Removal of fluids from ELVs is 100%,
- Separation and recovery of metals from ELVs is 100%, and
- Scrap tires weighing on an average 20lb per tire.

Table 2.2: Items recovered from ELVs in US

Fraction	Total Quantity (per 13.5 million ELVs*)		% of Total	Quantity per ELV	
	[million metric tons]	[million short tons]		[kg/ELV]	[lb/ELV]
Recovered Ferrous Metals	13.4	14.7	68%	989	2180
Recovered Non-Ferrous Metals	1.7	1.8	9%	122	270
ASR**	2.8	3.1	14%	206	454
Fluids	1.1	1.2	6%	83	183
Scrap Tires	0.5	0.5	2.5%	36	80
Total ELV	19.4	21.4	100%	1420	3165

Considering 13.5 million ELVs recycled every year as stated earlier, where fluids contribute 6% by weight from ELVs. The calculation results in recovery of approximately 83 kg of fluids in U.S., which poses a substantial savings for the country to have proper drainage procedures from ELVs.

However, the registration of new motor vehicles in India is certainly comparable to the U.S. data available and therefore, the number of vehicles to be retired in India would account in millions. From the above scenario, it is quite clear that the recovery of fluids certainly provides significant profits for the country to develop an effective and standardized drainage procedure from the ELVs.

Hence, the above-mentioned facts allowed this research study to be carried out and to perform analysis on the data gathered through online survey and facility visits to propose an innovative drainage procedure for automotive recycling in India.

The figure 2.4 [Susan Beaulieu, 2005] illustrates the simplified dismantling process along with parts and residues obtained during the process. The recovered ferrous and non-ferrous metals are recycled. The ferrous metals are recycled as alternative feedstock for steel mills [Staudinger, 2001]. The non-ferrous metal fraction usually requires additional processing and treatment to separate the materials into individual metal fractions to be further used for metal refining.

2.7 Removal of fluids

There is an environmental burden associated with waste/emissions produced by an abandoned ELVs i.e. principally leaking of vehicle fluids into the environment during the drainage procedure. In addition, traditional scrap/salvage yards, due to the historic low-tech nature of operations, operate with little regard for environmental protection and are the major concern.

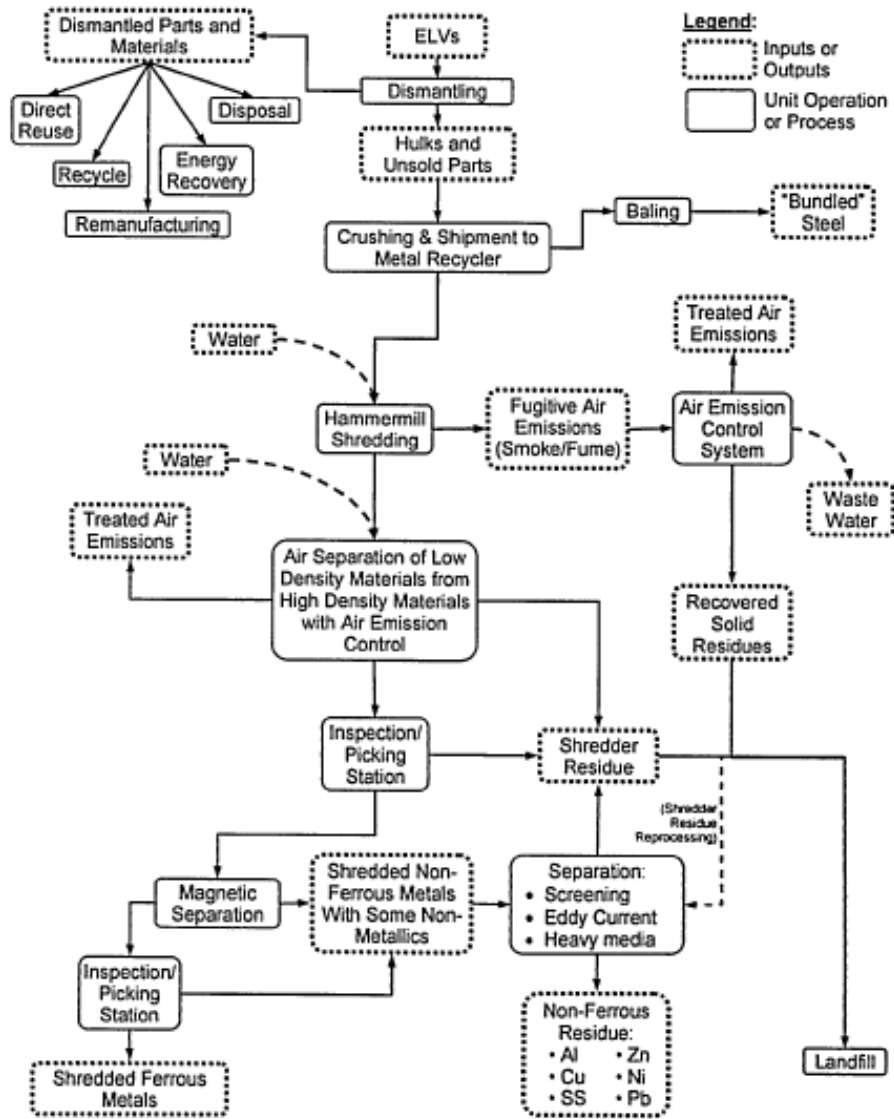


Figure 2.4: Simplified schematic diagram of a typical ELV process

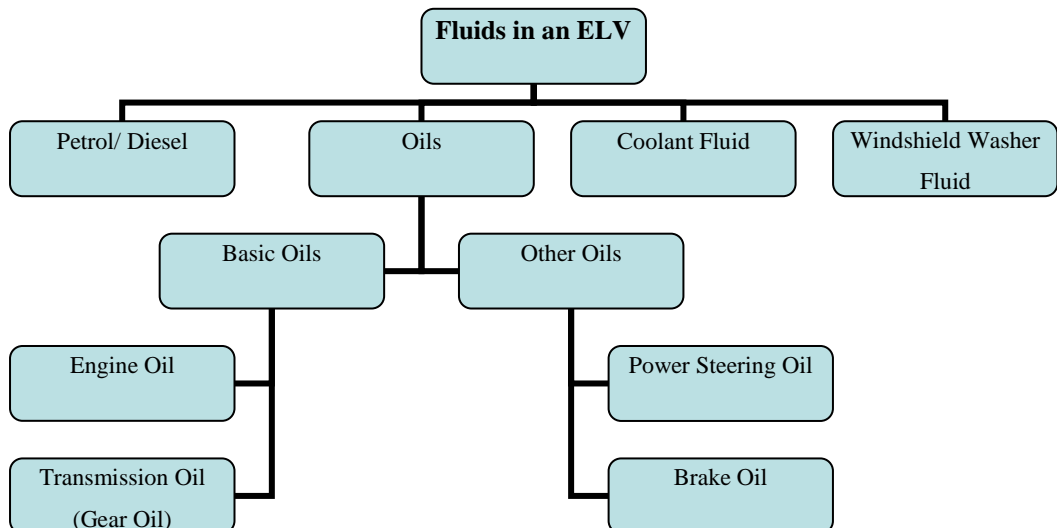


Figure 2.5: Automotive Fluids in an ELV

The different fluids removed from an end-of-life vehicle are mentioned in the figure 2.5 shown above. The removal of the fluids from the vehicle involves either manual or automatic method. In the field of fluid evacuation fuels, oils (engine and transmission) and coolant are considered the 'basic' and main fluids to be removed. They represent approximately 80-85% of the total fluids present in an ELV. The remaining fluids comprises of brake oil, power steering oil and windshield washer fluid.

The fluids drained out from the vehicle are flammable and pose great threat to the environment. The storage of flammable liquids is one of the major concerns if kept in consideration could save the hazards of fire and explosion involving either the liquid or the vapor given off from it. Fires or explosions are likely to occur when liquid or vapor is released and is exposed to a suitable ignition source, or alternatively, when a heat or fire source comes into contact with the container.

However, there are other physical properties of the liquid, which provide information about the potential hazards such as flashpoint, viscosity, etc. Flashpoint is defined as the lowest temperature at which a liquid gives off vapor in sufficient quantity to form a combustible mixture with air near the surface of the liquid under specified conditions. Generally, a liquid with a flashpoint below the ambient temperature of the surroundings will give off sufficient vapor to mix with air and be ignited. Whereas, the liquids with a flashpoint greater than ambient temperature are less likely to give off a flammable concentration of vapor. Hence, the lower the flashpoint of a liquid, the higher the risk.

On the other hand, viscosity of the liquid is also significant as it determines how far any spilt material will spread and therefore the size of any exposed surface. The flammable liquids can pose a health hazard if they are ingested, comes into contact with skin or eyes, or their vapors are inhaled. This is an essential input parameters for the analysis and design phase of the research study to develop a method or process which would eliminate the health hazard of the workers and allow us to achieve the goals of this research study.

During the literature review, five general principles were identified for ensuring that the risks of fire and explosion from the storage of flammable liquids in containers, are controlled and minimized. The principles have been described below:

- Ventilation: there should be plenty of fresh air where the containers are stored. Good ventilation would allow vapors given off from a spill, leak or release, will be rapidly dispersed.
- Ignition: ignition source could include sparks from electrical equipment or welding and cutting tools, hot surfaces, smoking, and open flames from heating equipment.

- Container: the flammable liquids should be stored in a suitable container and located in a safe place, such as a remote sump or away from the facility.
- Exchange: precaution needs be taken to ensure that flammable liquids should not be exchanged during the operations and stored in separate containers.
- Separation: the flammable liquids must be stored well away from other processes and general storage areas by a physical barrier, wall or partition.

As mentioned in the principles discussed earlier, separation of the stored fluids from the processing area could minimize the fatal accidents largely. According to a report by Health and Safety Executive [Health and Safety Executive, 1998], it is recommended that flammable liquids are stored well away from other processes and general storage areas. It has been observed that if the containers are stored outside in the open air it needs to be located in a well-ventilated area and away from sources of ignition. In addition, the container should be stored within a clearly defined area on an impervious surface, at a minimum separation distance as shown in the table below. The distances are based on what is considered to be a good practice and have been widely accepted by the industry. [Health and Safety Executive, 1998]

Table 2.3: Minimum separation distances

Quantity stored in <i>Litres</i>	Distance from occupied building, boundary, process unit, fixed ignition source in <i>meters</i>
Up to 1000	2
1000 – 100 000	4
Above 100 000	7.5

The information in Table 2.3 provides assistance in meeting the objectives of this research study and recommends an appropriate location of storage container from the drainage location.

Therefore, the required literature related to the storage and drainage of the automotive fluids has been studied to prevent any dangerous situations arising at the proposed facility, which has been discussed in detail in the following chapters. In addition, in-depth knowledge has been gained by studying the hazards of the fluids to the environment and health and safety of the workers.

As mentioned earlier, there are different fluids present in a vehicle. However, for the purpose of this study the focus has been on the four fluids: engine oil, gear oil (transmission oil), coolant, and petrol/diesel. An extensive literature review of the oils has been carried out to gain in-depth knowledge about their respective properties and environmental effects.

2.8 Engine Oil

The engine oil acts as a lifeline for the engine. If the quality of the engine oil is good it increases the life of the engine and resulting in fewer breakdowns due to engine failure. The typical engine oil consists of hydrocarbons with between 18 and 34 carbon atoms per molecule. In addition, one of the most important properties of engine oil in maintaining a lubricating film between moving parts is its viscosity. Therefore, the companies prefer synthetic engine oil as they have high viscosity indices and high temperature oxidative stability.

However, the concern is regarding the disposal of engine oil. If it is disposed of at a used oil collection facility, it can be recovered and re-used while minimizing threat to humans or the environment but keeping in mind that no other substances are mixed with used oil. Unfortunately, not all used engine oil is disposed of appropriately in India. Used engine oil ends up in landfill when put into containers in household trash bins. Inappropriate uses include pouring onto weeds, spraying on roads as a dust suppressant, and pouring it down the drain. These practices are harmful because the used oil can then enter the soil and leach through to contaminate ground water.

Groundwater contamination results when oil absorbs through soil layers and makes its way into lakes, streams, and rivers. These freshwater areas take on poisonous materials that harm fish and surrounding wildlife. If the engine oil enters the soil, it contaminates the soil and pose a significant threat to soil ecosystem balances and environmental health overall.

In addition, the effect of engine oil in water is a visible pollutant, floating as a scum on the surface. This oil scum stops sunlight and oxygen from getting into the water, affecting fish and water plants. It kills fishes, frogs and other animals that breathe from the water's surface. Used engine oil is incredibly toxic stuff and a gallon can contaminate one million gallons of water.

Recycling the used engine oil prevents it out of the rivers, lakes, streams and even the ground water. In many cases, that means keeping it out of the mixing with drinking water, off the beaches, and away from wildlife.

Fortunately, used engine oil is dirty rather than worn out, so it can be recycled. As such, it should be disposed of at a local recycling or disposal facility. Before disposal, used engine oil should be stored in a plastic or metal container with a secure lid, rather than dumped in a landfill or down the drain. Used engine oil should never be mixed with other substances such as antifreeze, pesticides, or paint stripper.

Used engine oil is recycled in several different ways. It can be reprocessed/re-refined into fuel to heat and cool homes. Engine oil can also be burned in furnaces for heat or in power plants to generate electricity for homes, businesses, or schools. It can be blended for marine fuels, mixed

with asphalts for paving, or used to fuel industrial burners. Used engine oil can be used in specially designed municipal garages, space heaters, and automotive bays. Finally, used engine oil can be re-refined into lubricating oils that meet the same standards as virgin or new oil. All of these methods of recycling help to conserve valuable energy resources.

Re-refining is an energy-efficient and environmentally beneficial method of managing used oil. The process of re-refining of used engine oil is broken down into two steps vacuum distillation and hydro finishing. The re-refining of used oil takes only about one-third the energy of refining crude oil to lubricant quality. It takes 42 gallons of crude oil, but only one gallon of used oil to produce a half gallon of new, high-quality lubricating oil that can be used in car engines. By recycling engine oil, we reduce the need for extraction of crude oil and the associated environmental impacts of that activity. The economic benefit to the country is that it will provide time to develop alternative fuels and lessen dependence on foreign oil suppliers for the oil. [Florida Department of Environmental Regulations, 1990]

2.9 Coolant

The coolant used in the vehicles is a solution of a suitable organic chemical i.e. ethylene glycol in water. It is a fluid which flows through a device to prevent its overheating, transferring the heat produced by the device to other devices that use or dissipate it. A coolant has high thermal capacity, low viscosity, and chemically inert. Ethylene glycol is a synthetic liquid is odorless, but has a sweet taste.

Ethylene glycol can enter the environment through the disposal of products that contain it. Ethylene glycol in water and in soil will breakdown within several days to a few weeks. In addition, the public is exposed to ethylene glycol through skin contact when using antifreeze. Accidental or intentional ingestion of larger amounts of ethylene glycol can cause serious illness or death. When ethylene glycol breaks down in the body, it forms chemicals that crystallize, and the crystals can collect in the kidneys and effect its functioning [Ethylene Glycol, 2007].

The separation of ethylene glycol from the water mixture can be obtained by performing the following techniques:

- i. Nano filtration,
- ii. Pervaporation separation using sulfonated poly membranes. and
- iii. Pervaporation separation using cross-linked chitosan membranes.

2.10 Transmission Oil (Gear Oil)

Gear oil is a fluid lubricant used in gears (gearboxes) for reduction of friction and wear of the gear tooth surfaces, removal of the heat generated by the operating gear and corrosion protection of the gear parts. It is of a higher viscosity to protect the gears and usually is associated with a strong sulfur smell. Gear oils provide reliable, efficient (low friction), low maintenance operation of gears at different speeds, temperatures, oil contaminations. According to the Society of Automotive Engineers (SAE) viscosity grading system, all oils are divided into two categories i.e. monograde and multigrade gear oil.

The most commonly used gear oil in the vehicles is synthetic gear oil. The viscosity of synthetic oils according to the ISO grading system is between 32 to 6800. Synthetic gear oils are used for gears operating under extreme conditions: very low or very high temperatures, high pressures. Viscosity of gear oil depends on the temperature; therefore, oil selected for a particular gear should provide its reliable operation within the expected temperature range. The low temperature limit of gear oil is 9°F (5°C) higher than its pour point (the lowest temperature, at which the oil may flow).

The gear oil removed previously is stored in large containers situated outside the working space. However, during the removal of gear oil from the vehicle it has been observed that spillage occurs on the ground and can affect the environment and the health of the worker operating the fluids.

The used gear oil is insoluble, persistent and contains toxic chemicals and heavy metals. It is a major source of oil contamination of waterways and can result in pollution of drinking water sources. An exposure to gear oil for longer period might result in eye irritation. If the used gear oil and the contaminants it contains are disposed of inappropriately and released into the environment, they can harm humans, plants, animals, and fish.

If ground soil is contaminated it may result in the death of insects or animals that burrow and live in the soil. Contaminated soil may lead to the poisoning of insects and rodents needed to control pests that can damage crops or spread disease. Moreover, the gear oil may find its way into groundwater and may eventually wind up in watering holes for livestock or even wells used for drinking water. Rains can carry toxic chemicals into reservoirs or waterholes. Therefore, gear oils pose a threat to the water as well.

Considering that just one gallon of used oil can contaminate up to one million gallons of water, it's essential to dispose of used oil the right way. Finished gear oil is generally made from 85% base oil and 15% additives. The "oil part" of motor oil does not really wear out. The recycled oil in goes through a multi-stage refining process to remove contaminants and additives to create

fresh base oil that can be used for various purposes. Reprocessing and re-refining involve operations, which will separate and remove contaminants in used oil so that this oil becomes suitable for reuse. Contaminants removed in this process will be part of waste streams that must be disposed of in an environmentally sound way.

Recycled oil reduces impact on the environment vs. oils made without recycled content. The amount of energy used to find, drill, transport and refine crude oil is significant. Recycled oil eliminates or reduces many of these steps, and therefore has a smaller "carbon footprint," reduces energy consumption and lowers pollutants that contribute to climate change. Recycled oil also helps reduce the need for new drilling and crude refining, by reusing the oil that has already been pulled out of the ground. [Florida Department of Environmental Regulations, 1990]

The journal articles and reports related to the research study have been discussed in a chronological order in the next section.

2.11 Theoretical models

Wolfe, (1992)

But, during the last four decades, the used oil recycling market has followed the same Darwinian evolution as many U.S. businesses. The firm then re-refined the lube oils and sold back them as a product. As for making money in the market, Ray states, "When we sell the recycled lube oil, we're selling into a commodity market. We tend to follow the price for base oil."

- Recycling/reusing are terms used to describe any kind of reuse, including turning lubricating oils into gasoline or burning them as fuel.
- Re-refining refers to the loop-closing process of cleaning and re-refining used lubricating oils to produce specification-worthy new lube oil.

Safety-Kleen Inc. is a public company in the Canada and US is one of the world's largest oil refineries. They have a plant located at Breslau, Ontario with an annual capacity of 35 million gallon. The company charged approximately \$50 for up to 250 gallons of used oil and use their own trucks to pick it from the facilities. After the re-refining process the used oil the new used lube oil accounts for 65 %, asphalt extender for 7% and the rest fuel oils and etc. These end products are sold to blenders, compounders and retail asphalt customers.

Miller, (1995)

This article discusses about the coefficient alpha and its uses. The methods of approximating test reliability are described in the article; equations have been derived for each method, and α are shown to be an internal-consistency approximation to test reliability. Cronbach's alpha is commonly used index of test reliability. It was developed by several researchers during the first half of this century and was named by Cronbach in 1951, the first writer to recognize its general usefulness. Test score reliability is a variance ratio equal to the true-score variance of the test scores divided by the total variance of the test scores. Test scores have a higher reliability when there is a large genuine variation in the population of examinees. Cronbach's alpha can be applied to tests with any number of items or components. High value of Cronbach's alpha means inter-item correlation is significant and internally consistent.

Gregory et al., (1997)

The primary objective of this journal article was to apply life cycle design tools to guide the improvement of fuel tank systems. Two alternative fuel tank systems used in a 1996 GM vehicle line were investigated: a multi-layer high density polyethylene (HDPE) tank system, and a steel tank system. In-order to understand the fuel tank design, its specifications and to compare them this article was considered. The scope of the study has been described in a tabular manner in the table 2.4.

While both systems meet basic performance requirements, the plastic tanks have several advantages over the steel tanks which are:

- i. Lighter weight
- ii. More durable
- iii. Improved compartment space utilization
- iv. Cost-efficient
- v. Safe
- vi. Flexible – allows for the expansion of vapours and bending during an accident

However, Indian cars primarily use steel tanks whereas North American cars consider using plastic tanks due to above mentioned factors. Information about Indian market about the fuel tanks was gathered after talking to the various scrap dealers in Chandigarh and Patiala. The plastic tanks have been considered by Honda and Ford only in India till date while the rest still use steel fuel tanks.

Table 2.4: Boundaries and Major Assumptions of Fuel Tank Systems

LC Stage	Steel Tank	HDPE Tank – Plastic Tank
Material Production	<ul style="list-style-type: none"> • The paint applied to the steel straps was modeled as steel because of the lack of data on the amount of paint applied 	<ul style="list-style-type: none"> • HDPE was substituted for the following components of the multi-layer tank: <ul style="list-style-type: none"> ▪ Carbon Black ▪ PE-Based adhesive ▪ EVOH • PVC applied to straps was assumed to be emulsion of PVC
Manufacturing	<ul style="list-style-type: none"> • None of life cycle burdens of process materials were inventoried due to data availability • Scrap rate of 2% was estimated for HDPE injection molding process • No scrap was considered to be generated in steel scrap fabrication • Copper is used as a process material in steel tank fabrication • Manufacturer: Delhi 	<ul style="list-style-type: none"> • No scrap was considered to be generated in steel scrap fabrication • The energy consumption for tank blow molding was based on generic blow molding/ injection molding process • Manufacturer: Walbro
Other Specifications	<ul style="list-style-type: none"> • Volume: 31 gallons • Total weight (including all components): 21.92 kg • Design life: 11 years or 110,000 miles based on an average of 10,000 miles of vehicle travel/year. 	<ul style="list-style-type: none"> • Volume: 34.5 gallons • Total weight (including all components): 14.07 kg • Design life: 11 years or 110,000 miles based on an average of 10,000 miles of vehicle travel/year.
Use	<ul style="list-style-type: none"> • Contribution of tank system weight to use phase energy consumption is calculated by assuming that weight is linearly proportional to fuel consumption. 	
End-of-life	<ul style="list-style-type: none"> • All components are considered to be shredded. Shredding fuel requirements were considered to be independent of the type of material shredded or shape of the part • Steel is assumed to be recovered at 100% • All HDPE is assumed to be landfilled 	

R. Y. M. Huang, (2002)

Pervaporation separation of ethylene glycol aqueous solutions was carried out using sulfonated poly (ether ether ketone) homogeneous membranes. The membrane relaxation in separation process was observed and alleviated by heat treatment. The heat-treated pervaporation membranes experience further relaxation in the separation process by the swelling interactions of the feed mixtures before steady-state transport is reached. Membrane performance is investigated in terms of sorption and pervaporation separation. The preferential sorption and diffusion of water in the membranes were observed.

Eichler et al., (2003)

This paper investigates the use of partial correlation analysis for the identification of functional neural connectivity from simultaneously recorded neural spike trains. Partial correlation analysis allows one to distinguish between direct and indirect connectivities by removing the portion of the relationship that would effect the results. The basic idea of the partial correlation analysis is to measure the association between the two processes after the linear effects of the multivariate process have been subtracted. Therefore, the partial correlation analysis only revealed the connectivity relative to the set of monitored neurons.

Peng et al., (2003)

The research conducted used multinomial logistic model to predict adolescent behavioral risk. The results of the study showed that gender, intention to drop from the school, family structure, self-esteem, and emotional risk were effective paramters for their study. Logistic regression is a promising statistical technique used to predict the likelihood of a categorical outcome variable. As stated in the article, multinomial logistic regression is well suited for describing and testing hypotheses about relationships between a categorical dependent variable and one or more categorical or continuous explanator variables. Furthermore, it provides an effective and reliable way to obtain the estimated probability of belonging to a specified factor. In-order to assess the effectiveness of the multinomial logistic regression results, goodness-of-fit statistics predicts the probability. Goodness-of-fit statistics assesses the fit of a logistic model against actual classifications i.e. high, medium or low level of risk. Mostly two descriptive measures of goodness-of-fit are presented for the model: R^2 indices defined by Cox and Snell and Nagelkerke. According to the results obtained, these indices are variations of the r-squared concept defined for the ordinary least squares regression model.

Boughton et al., (2004)

The 1 billion gallon of used oil generated in the U.S. each year are managed in three primary ways: re-refined into base oil for reuse, distilled into marine diesel oil fuel, and marketed as untreated fuel oil. Management of used oil has local, regional and global impacts. The human health and environmental trade-offs of the management options are quantified and characterized. A life-cycle inventory showed that 800 mg of zinc and 30 mg of lead air emissions may result from the combustion of 1 L of used oil as fuel (50- 100 times that of crude-derived fuel oils). As an example, up to 136 mg of zinc and 5 mg of lead air emissions may be generated from combustion of over 50 Mgal of California generated used oil each year. An impact assessment showed that heavy metals-related toxicity dominates the comparison of management methods. Zinc and lead emissions were

the primary contributors to the terrestrial and human toxicity impact potentials that were calculated to be 150 and 5 times higher, respectively, for used oil combusted as fuel than for re-refining or distillation. Instead, both the re-refining and distillation methods and associated product markets should be strongly supported because they are environmentally preferable to the combustion of unprocessed used oil as fuel.

Beaulieu et al., (2005)

To improve our understanding of the ramifications of the end-of-life vehicle (ELV) management practices currently employed in North America, life cycle assessment (LCA) methods have been used to analyze ELV dismantling processes, ELV shredding and baling systems, and shredder residue (SR) recovery/treatment processes. Furthermore, it was proposed to use the ELV studies to demonstrate how the LCA process helped to identify and evaluate trade-offs between alternative technologies and unit operations for handling and processing ELVs.

Subsequently, “successful” ELV practices, unit operations, and/or technologies have been identified, and their practical constraints and issues of concern examined in the report. Using the case study information and supplemental data, a life cycle inventory (LCI) of typical ELV management processes has been constructed.

In-order to improve the material recovery and recyclability life cycle assessment approach was considered to identify the key issues which were:

- Regulatory aspects of ELV management in North America and the impact of the European Union (EU) ELV Directive.
- Issues that impede effective recovery and recycling of scrap materials (e.g., plastics) from pre-shredder/baler ELVs and from shredder residue, such as: contamination from ELV shredder/baler feed streams (e.g. mercury, lead, chromium); contamination from co-mingled non-ELV shredder/baler feed materials (e.g. PCB, mercury, lead, cadmium);
- Market re-introduction issues with respect to products and materials recovered from ELVs, such as the value of virgin materials versus recycled materials.

Hence, this report enlightened us to consider the reusability and price issues of the recycled parts in the market while considering the maximization of the material recovery from ELVs.

P. Srinivasa Rao, (2007)

A method for cross-linking membranes using phosphoric acid in alcohol baths was studied for the separation of ethylene glycol/water mixtures. The cross-linked membranes were subjected to sorption studies to evaluate the extent of interaction and degree of swelling in pure as well as

binary mixtures of the two liquids. In order to gain a more detailed picture of the molecular transport phenomenon, sorption gravimetric experiments were performed at 30 °C to compute diffusion, swelling, sorption, and permeability coefficients of phosphorylated chitosan (P-CS) membranes in the presence of ethylene glycol and water. The effects of experimental parameters such as feed composition, membrane thickness, and permeate pressure on separation performance were determined. The separation factor was found to improve with decreasing feed-water concentration whereas flux decreased correspondingly. Increasing the membrane thickness decreased the flux but had a less profound effect on the separation factor. Higher permeate pressure caused a reduction in flux and an increase in selectivity.

Nourreddine, (2007)

Currently, about 75% of end-of-life vehicle's (ELV) total weight is recycled in EU countries. The remaining 25%, which is called auto shredder residues (ASR) or auto fluff, is disposed of as landfill because of its complexity. It is a major challenge to reduce this percentage of obsolete cars. The European draft directive states that by the year 2006, only 15% of the vehicle's weight can be disposed of at landfill sites and by 2015, this will be reduced to 5%. The quantities of shredder fluff are likely to increase in the coming years. This is because of the growing number of cars being scrapped, coupled with the increase in the amount of plastics used in cars. The figure 2.6 shows the recovery path of ELVs. The shredding of ELVs results in 75% recovery of steel which can be used in steel manufacturing industry. The remaining is considered fluff and disposed of as landfill.

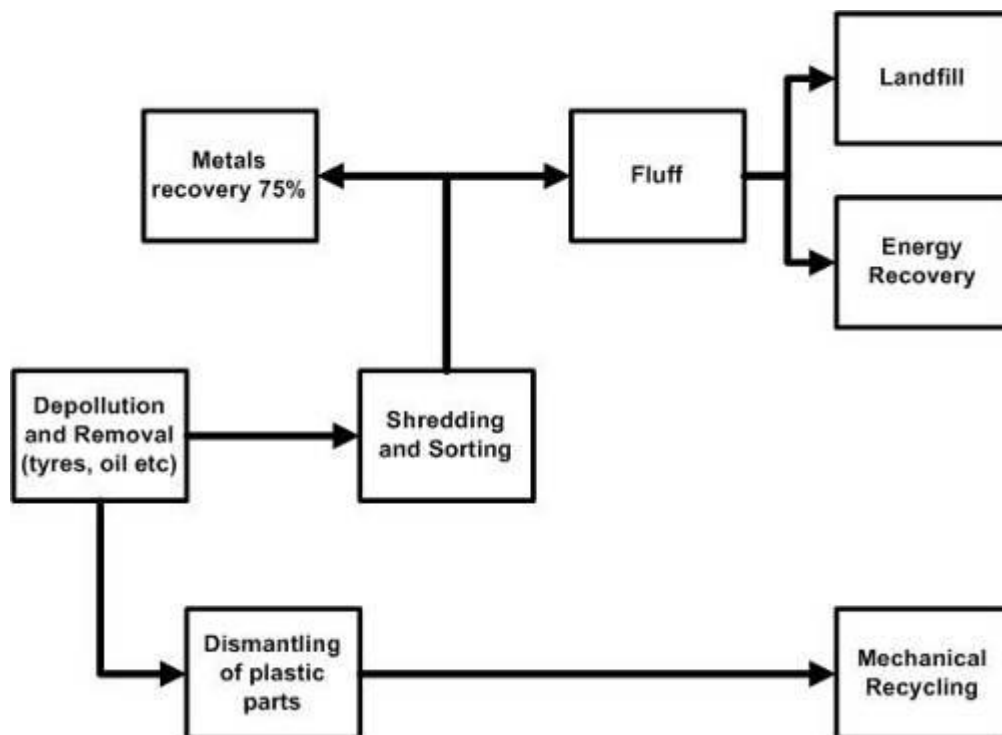


Figure 2.6: Recovery Routes of ELVs

The above figure clearly depicts that the materials used in vehicles should be maximized to be recyclable material to prevent environmental pollution and to save the natural resources.

Grunske et al., (2007)

Failure Mode and Effect Analysis (FMEA) is a method for assessing cause-consequence relations between component faults and hazards that may occur during the lifetime of a system. The analysis is typically time intensive and in-formal, and for this reason FMEA has been extended with traditional model checking support. A well-known technique for safety evaluation is FMEA, where a team of engineers identifies the effects and cause-consequence relationships of component failures on system-level hazards. Once a cause-consequence relationship is detected between a failure mode and a hazard, the likelihood of that hazard occurring is calculated and compared to its tolerable hazards rate. If the system does not pose a non-tolerable risk then the system is considered safe, otherwise iterative steps are taken to reduce the probability of the hazard occurring.

Beaulieu et al., (2008)

This report discusses about the 4 R's of the material recovery from end-of-life vehicle that involve the dismantling and shredding procedure of the vehicle in North America. End-of-life is the least studied phase of the vehicle life-cycle. Dismantling and shredding are the principal processes used for vehicle end-of-life (VEOL) management in Canada and the U.S. and are typically perceived as distinct processes, each one having its own unique challenges.

Dismantling typically precedes shredding, with vehicle parts and materials removed for direct reuse, for remanufacturing and reuse, or for recycling. Dismantling may be perceived as a non-preferred alternative, compared to shredding, because it is principally a manual process which can be cost prohibitive in the North America/western labour market. Because of the complexity in automobiles, significantly more needs to be known about dismantling, its benefits and impacts, its efficiencies and inefficiencies, and its relation to other ELV management processes.

Shredding involves the mechanized processing of ELV hulks and other metal-rich scrap materials using a hammer-mill but this process results in shredder residue (SR), the bulk volume remnants that may be contaminated or toxic. Shredder residue solutions principally focus on post-shredding solutions, some of which have limited success to date. An alternative approach to improving shredding efficacy would be to optimize dismantling prior to shredding, with the goal of reducing SR volumes, increasing materials recovery, and reducing SR contaminants.

Hoeher, (2009)

This survey report resulted from a total of 205 responses of which 151 are US Automotive Recyclers Association (ARA), 49 Canadian along with four Australian and one British recycler.

Elimination of fluid double handling, the use of a single drainage bay/ rack and the reduction in drainage time were the main areas addressed. The dollar equivalent savings from those areas was approximately \$24,800 per year for an average sized automotive recycling operation, more than twice the amount of the average investment amount of \$ 11,100.

As seen from a volume perspective the quantity of fluids drained by all ARA members is truly staggering. The amount of petrol/diesel extracted can power 18,834 vehicles for an entire year based on the average mpg (miles per gallon). Furthermore, the quantity of other oils taken from ELVs can heat 5,684 average sized US households for a full year.

This report illustrates the re-usability of the fluids present in a vehicle and the amount of savings that can be incurred if the proper de-pollution systems are setup in a country. Moreover, this would allow us to save the natural resources used to produce heat in homes and the industry.

Sarkisian, (2009)

The journal article proposes that multinomial logit models are used when there are multiple categories that cannot be ordered. The order of categories is unimportant for the analysis to be performed. Multinomial logit model is equivalent to simultaneous estimation of multiple logits where each of the categories is compared to one selected so-called base category. However, if they were estimated separately, information would be lost, as each logit would be estimated on a different sample. To avoid that, multinomial logistic regression analysis is used.

Israel, (2009)

This journal article discusses about the phases of data analysis. The number of phases that an individual conducts will depend on the purpose of the evaluation, as well as available time and resources. Extension faculty who conduct less rigorous evaluations will use fewer steps while those with more rigorous evaluations will follow more steps. Initially, the screening of the data entered is performed to investigate any errors. It is important to identify and correct data handling errors as data analysis depends on the quality of the data entered. If data is typed into a computer file using a text editor or word processing program, a single coding error can cause a whole line of data to be mis-aligned. Once this preliminary step has been completed, the data is ready for analysis.

After screening the data for errors, the next step in the data analysis process is to select the key indicators for the analysis. By selecting a limited number of key indicators from the pool of

available variables, the analysis can be more easily focused. First, the key indicators or impact variables are identified that are included as measurable objectives in the Plan of Work. These data may be the same key indicators that should be use for the evaluation.

For each key indicator, determine whether pre-program and post-program data are available or post-program data only. The latter may be such that clientele report retrospectively about whether they adopted a practice or changed some behaviour.

Once the key indicators have been selected, the next step is to address the question of how much change is there. The purpose is to quantitatively describe the amount of change in one or more measures. Several statistics can also be used to describe and test the significance of difference between the input and output parameters.

- A t-test can be used to compare the average score of program participants with the average score for nonparticipants. The t-test is used with variables measured at the interval or ratio level, such as income or age.
- Correlation and regression can be used to examine whether the score of the output indicator increases with an increase in the extent of input participation.

There are other statistical tools as well which have been applied for the purpose of data analysis and will be discussed more in detail in the forthcoming sections of this report.

The final and most complex phase of the data analysis involves examining the effect of your program on changes in impact indicators while controlling for the effects of other factors. Analysis in this phase involves the use of either tabular analysis or multi-variate statistical analysis techniques, such as regression, analysis of variance, and logistic regression. Some of the techniques mentioned have been implemented in the study to analyze the data statistically.

DEFR et al., (2011)

The fluids that are removed from the end-of-life vehicle (ELV) need to be stored in separate containers in an outside storage area to prevent fire hazards. The report mentions that the fluid drainage process in an ELV should start with the engine oil, as it requires maximum time. The other fluids can be drained out simultaneously.

Engine oil – made from heavier, thicker petroleum hydrocarbons between 18 and 34 carbon atoms per molecule. It also has a higher viscosity index to maintain lubrication film between the moving parts. The oil filter needs to be removed prior to the drainage of engine oil.

Transmission oil – this oil is contained in both manual and automatic gearboxes in a vehicle. This oil is also of a higher viscosity to protect the gears. The gear oil is also drained out using gravity technique with a minimum volume of 5 litres.

Power steering fluid – it is a hydraulic fluid. This fluid has to be removed from both the reservoir and the connecting hose using gravity techniques.

Brake fluid – it is also a hydraulic fluid. This fluid has to be sucked from the reservoir and the brake pipes and cylinders. Several health and safety issues are associated with its removal and special equipment's need to be used for fluid extraction.

Coolant – A fluid that flows through a device to prevent its overheating. It has high thermal capacity, low viscosity, and non-toxic. It is usually a solution of ethylene glycol in water to withstand temperatures below 0 degrees Celsius. This fluid is also drained by gravity from the bottom of the vehicle.

Windshield washer fluid – this fluid used in the vehicles is usually distilled water otherwise specified by the manufacturer.

Petrol/diesel – they are present in the fuel tanks located at the bottom of the vehicle. They are extremely volatile liquids, which gives flammable vapors at very low temperatures. In addition, petrol vapors are heavier than air and do not disperse easily in the still air conditions. Flammable vapors are released when petrol/diesel is handled, extracted, transported between storage tanks. These vapors remain in the fuel tanks for long time even after they have been emptied out. It can be removed through various manual methods and by using special equipment that drill a hole into the tank and use suction to drain the fuel out.

Starkweather et al., (2011)

Multinomial logistic regression is used to predict categorical placement in or the probability of category membership on a dependent variable based on multiple independent variables. The independent variables can either be dichotomous (i.e. binary) or continuous (i.e. interval or ratio in scale). Multinomial logistic regression analysis is a simple extension of binary logistic regression that allows for more than two categories of the dependent or outcome variable. Like binary logistic regression, multinomial logistic regression uses maximum likelihood estimation to evaluate the probability of categorical membership. Multinomial logistic regression is often considered an attractive analysis because; it does not assume normality, linearity or homoscedasticity. This regression analysis is preferred since the choice of membership in one category is not related to the choice or membership of another category. The logistic coefficient i.e. β is the expected amount of

change in the logit for each one unit change in the predictor variable. The closer β is to zero, the less influence the predictor has in predicting the logit.

2.12 Techniques for the removal of fluids

The safe removal of fluids in developed nations requires the use of special de-pollution systems to reduce the time, maximize profits and reduce work-place injuries. The systems have been studied to determine the working and record the benefits of each system in order to develop a system for automotive fluid drainage in India from end-of-life vehicles.

Gary et al., (2003)

In this system, the vehicle is elevated on a lift and a puncturing apparatus, movable along both the X and Y-axis, is positioned under the fuel tank. The apparatus punctures the fuel tank and the Petrol/Diesel is funneled through the apparatus into a receptacle. Tubes are inserted into the different fluid containing reservoirs under the hood and drained into different receptacles. The fluid stored is pumped into a gravity-separating unit, which divides the mixture into its component fluids according to their densities.

Problem with this system is that there are oil spills while draining out the fluids, lower workplace height for the workers could result in workplace injuries. Moreover, the gravity suction system might not be an effective way of separating the fluids. This alternative could be improved by separating the fluids in the beginning and increasing the workplace height to improve worker's efficiency.

Superior Recycling Solutions (SRS), (2009)

The fluid recovery system developed by SRS is highly efficient. Since, the system is very efficient and environmental friendly it is widely used in the industry. Due to the high initial costs, it is not widely used in the industry. The table 2.5 illustrates the features of the depollution system.

Reiser et.al, (2009)

The SEDA Easy Drain is an ideal solution to drain ELVs of all liquids. This system extracts fluids in a clean and efficient manner while improving the safety for the worker. The machinery is compact, durable, provides fast and cost-effective solution.

This system is capable of processing 25 – 30 cars per day and removes up to 98% of all the fluids without any spillage. The Petrol/Diesel is drained from the fuel tank using automatic suction system and directly transferred to the storage tanks in the yard.

Table 2.5: Advantages vs. Disadvantages of Fluid Recovery System by SRS

<u>Advantages</u>	<u>Disadvantages</u>
Maximizes the number of vehicles drained in a day (60+ vehicles/day on a two drain technique)	Requires forklift to place the vehicle on the heavy duty frame
Workers do not have to handle/move any fluids	All fluids drain in one pan which are later separated
Reduces the number of workers required	Workers have to manually perform the drainage of fluids under the hood using suction pipes
Handles two cars simultaneously	Drills holes in the fuel tank to drain out Petrol/Diesel, which is still hazardous
Open workspace under lift	High capital equipment costs
No funnels/dollies to work around	
Completely removes all the fluids from the various tanks by tilting the vehicle	
Protects the environment by eliminating spills	

2.13 Questionnaire

As stated by (Lehto & Buck, 2008), a questionnaire is a list of questions presented to prospective respondents. The purpose is to collect information and sometimes to measure statistical accuracy. Since a large number of questionnaires can be distributed and the results can be easily summarized, the principal appeal of this technique is its relative low cost in quickly gaining access to many people. But, a well-designed questionnaire requires careful planning and consideration of potential problems that may arise. One of the major concerns is the validity and reliability of the responses. Thus implies that a systematic procedure should be followed during the design and development of the questionnaire.

The construction of questionnaire has been divided into four segments. Firstly, an introduction to the respondents regarding the concerned subject is provided which motivates them to answer the questions and provides any needed clarification. The next section enlists all the required questions to be answered by the respondent. The latter section typically inquires about the respondents general information such as name, email address and phone number. The final section of a questionnaire is the epilogue. In this section, the developer of the questionnaire thanks the respondent for participating in the survey. (Lehto & Buck, 2008)

The questionnaire designed for the research study was framed in a manner considering the important facts mentioned by (Lehto & Buck, 2008). The questions to be asked to the workers in both India and Canada needed to be framed in a manner such that they are self-explanatory and easy to answer by the concerned authorities. As a result, set of questions were brainstormed and a questionnaire was prepared. The initial questionnaire consisted of few questions and after several iterations a primary questionnaire has been prepared to gather the required data. Hence, a relevant and detailed questionnaire containing objective type questions with multiple choice answers pertaining to the desired conceptual framework was designed.

Figure 2.7 illustrates the screenshot of the online survey conducted to collect the data from Canadian Recycling companies. The online survey was designed in a manner such that it provided maximum information to the survey responder to answer the questions in a user-friendly method. Therefore, the first part of the online survey included a brief introduction about the research study, permissions from the Director of OARA to conduct the research study and lastly ensuring the respondents that the information provided would be kept confidential. Furthermore, the details about the company were asked in the survey followed by the questions related to the drainage methods. Lastly, the respondents were thanked for their valuable time and cooperation to fill in the survey.

Data Collection for Master's Project on
'Automotive Fluids Drainage'



**THIS PROJECT WORK IS BEING CARRIED OUT BY THE APPROVAL
OF MR. STEVE FLETCHER (EXECUTIVE DIRECTOR OF OARA)**

NOTE:

**IN PREVIOUS RESPONSES IT HAS BEEN OBSERVED THAT NAME
OF THE COMPANY AND LOCATION HAVE NOT BEEN MENTIONED.**

**I REQUEST YOU TO PLEASE FILL IN THAT INFORMATION AS WELL,
AS I NEED TO ANALYZE THE DATA ACCORDING TO LOCATION AS
WELL TO CARRY OUT THE RESEARCH WORK.**

**THIS INFORMATION IS CONFIDENTIAL AND WILL NOT BE USED FOR
ANY OTHER PURPOSES!**

Please tick the correct answer after reading the description of the question

1) Please enter your details for reference purposes only

*Name of the Company

*Location

*2) In-order to drain the fuel out from the car there can be several options.

- i. The car could be lifted up and then equipment can be used to drain the fluids out.
- ii. The car could remain on the ground and the worker slides under the car and uses a bucket to collect the fluids from it.
- iii. If there's any other method please mention the details about it so that it can be considered

Current procedure

Figure 2.7: Sample of Online Survey conducted

Several questionnaires were considered to design the questionnaire used for the purposes of this research study as seen in the Appendix – II.

2.14 Statistical Tools

The data obtained from the online survey and plant visits should be tabulated on a computer as it can quickly check for out-of-range and illogical responses. In addition, the reliability and validity of the responses obtained have been calculated by calculating Cronbach's Alpha coefficient value. In addition, the partial correlation coefficient measures the degree of linear association between two variables while keeping one of the factors constant and was calculated after validating the responses from the survey. Hence, to determine the relationship between the categorized input and output parameters multinomial logistic regression analysis has been performed. Additionally, the fitness of the model have also been computed by performing the goodness-of-fit tests for the research model. The results obtained have been discussed in the next few chapters.

2.15 Industrial Tools

Flow process charts are graphical and symbolic representations of work performed. Flow Process charts are widely used in industry to represent the entire sequence of a process and have been illustrated by analyzing the drainage process of petrol/diesel from ELVs. In addition, FMEA analysis has been performed to analyze the design characteristics relative to the planned manufacturing process to ensure that the resultant product meets customer needs and expectations. After the potential failure modes have been identified, corrective actions were taken to eliminate or continually reduce the potential for occurrence. Furthermore, the Pugh Matrix allowed the comparison of facility configurations leading ultimately to a proposed facility, which best meets, a set of criteria. Lastly, the breakeven analysis has allowed calculating the fixed costs, variable costs for the proposed drainage method and revenue generated from the fluids drained out from the vehicles. In addition, the breakeven point demonstrates the bare minimum time required for a company to cover the expenses occurred and to start earning profits.

2.16 Gaps in the literature

This chapter has presented the findings from literature on various key input factors required for the process/method development of automotive fluids drainage for the recycling industry. The review of past literature indicates sufficient gaps for the conduct of proposed research work. The following limitations may be noted:

- An enormous amount of research has taken place to explain the different techniques and tools present outside India for the drainage of the fluids. However, there are key parameters to be considered, for promoting technological improvements in the automotive recycling sector in India. The most of the writings do not cover the various factors together and thus fail to compare their relative importance in achieving the overall objective of process/method development for automotive sector.
- The enforcement of rules and regulations for dismantling of ELVs in different countries has been studied. There is a lack of studies providing perspectives on the consequences of not following the correct procedures during the drainage of the fluids.
- There is a lack of academic writings (both theoretical models as well as quantitative research) on the role of government as a facilitator of technical change in the automotive sector.
- Further, very few empirical studies and quantitative research have been reported to support the theoretical findings.
- Comparative analysis has not been conducted for dealing with current drainage procedures of petrol/diesel at a global level.

The present research work intends to bridge the gaps in literature and practices by suggesting an innovative method/process for automotive fluids drainage for automotive industry in India.

The competitive business environment is forcing organizations to perpetually seek ways of improving their products and services. The literature has provided us with an initial explanation of the various methods/processes currently in practice that makes certain countries more innovative than others. Hence, proposed method has finally been developed and presented to illustrate the technology development and its benefits in the automotive industry.

The next chapter introduces overall design of the study. It describes the various phases of research and the methodology adopted for carrying out the research study.

CHAPTER 3. DESIGN OF STUDY

3.1 Introduction

This chapter introduces overall design of the study, which includes methodology adopted for carrying out the research work and the various phases of study. The details of work proposed to be done in each phase; the tools, techniques and models used in the work have also been covered.

3.2 Methodology

The study has been carried out with a purpose to analyze the technology/process development capabilities of Indian automotive recycling industry through indigenous research initiatives and developing an effective strategic technology development process for the same. Considering, the wide and complexity of the current scenario and the fact that such studies can be carried out primarily by closely analyzing the approaches adopted by various organizations and the result thereof, it has been considered appropriate to carry out the research work under the overall framework of 'reverse engineering methodology'. Reverse engineering is the process of examination, understanding, and alteration of a system with the intent of implementing the system in a new form [Chikofsky & Cross, 1990].

3.3 Problem Conceptualization

The current problem regarding the automotive recycling industry has been formulated and a solution to the problem conceptualized by applying reverse engineering technologies. This methodology aims to make comparisons across different countries or cultures. This research methodology is simply the act of comparing two or more things with a view to discover something about one or all of the things being compared. In-order to understand the basic principle of the drainage and disposal of the fluids, it is very essential to visualize the current practices being followed in India and outside India. To gain the insight of the process, the relevant information has been gathered from the appropriate sources i.e. by physically visiting automotive centers and conducting online surveys.

3.4 Phases of Research

The present study comprises of two major parts namely 'Analysis' and 'Design'. Analysis includes all relevant information and data regarding the status of research subject in the engineering industry and corrective actions that can be applied. Design deals with developing a technology development

process using the information as collected and analyzed in the first part. Based on reverse engineering methodology, the research work has been carried out in three phases:

Phase I: Clarifying the context

Phase II: Understanding and assessing the situation

Phase III: Proposing a solution

3.5 Clarifying the context

In this phase, the need and scope of the research work is established. The reasons for the poor performance of Indian automotive recycling industry in the areas of technology development have been explored. Tactical issues for bridging the technology capability gap have also been assessed. Wide literature is available on drainage, disposal, harmful effects of the fluids drained out, and other related issues regarding technology upgradation.

3.6 Understanding and Assessing the Situation

The second phase assesses the status of technology development currently in practice and resulting performance indications in the automotive sector, through plant visits and questionnaire based survey. The questionnaire survey technique has been employed to collect data from the various companies of India and Canada.

3.6.1 Questionnaire Development

The study has been carried out in automotive recycling industry in India and Canada that have successfully implemented or are in the process of implementing technology innovation methods for the fluids drainage process. The questions to be asked to the workers in both the countries needed to be framed in a manner such that they are self-explanatory and easy to answer by the concerned authorities. As a result, set of questions were brainstormed and a questionnaire was prepared. The initial questionnaire consisted of few questions and after several iterations a primary questionnaire has been prepared to gather the required data. Hence, a relevant and detailed questionnaire containing objective type questions with multiple choice answers pertaining to the desired conceptual framework was designed.

The figures 3.1, 3.2 and 3.3 shown below are the sample pages of the questionnaire developed for the research study. The figure 3.1 illustrates the hard-copy version used to collect the data during the visits to the facilities whereas figure 3.2 and 3.3 depict the screenshots of the online survey conducted to collect the data from Canadian recycling companies.

Survey for Current Master's Thesis

Please tick the correct answer after reading the description of the question

Name:

Location of the company:

In-order to drain the fuel out from the car there can be several options.

- i. *The car could be lifted up and then equipment can be used to drain the fluids out.*
- ii. *The car could remain on the ground and the worker slides under the car and uses a bucket to collect the fluids from it.*
- iii. *If there's any other method please mention the details about it so that it can be considered*

1. Current procedure
 - a. Lift up the vehicle
 - b. Worker slide underneath the car
 - c. Other

According to the procedure chosen previously for draining the fluids from the car, which fluids are being drained out and please mention the time required for each of the fluids approximately. Fluids could be such as (petrol and diesel, engine oil, coolant oil etc.) .if any other fluids except the ones mentioned below are also being drained out please mention it as well.

2. Which fluids are being drained out? How much time is required for their drainage?
 - a. Petrol and Diesel
 - b. Engine oil
 - c. Brake Fluid
 - d. Transmission oil
 - e. Coolant
 - f. Windshield washer fluid
 - g. Power steering fluid
 - h. Other

Draining of fuel (i.e. petrol and diesel) from the ELV's requires a specific technology or an equipment to drain them out efficiently. Considering the existing systems being implemented in UK, USA, Canada and other Asian countries following technologies have been developed.

Drain: in this method the port outlet underneath the car is opened and the fluid is collected in a bucket or a container and transported into a bigger container afterwards.

Figure 3.1: Sample Hard-Copy Questionnaire Version

Data Collection for Master's Project on **Free Online**
'Automotive Fluids Drainage' **Surveys.com**

Online Surveys

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OF MR. STEVE FLETCHER (EXECUTIVE DIRECTOR OF OARA)**

NOTE:

**IN PREVIOUS RESPONSES IT HAS BEEN OBSERVED THAT NAME
OF THE COMPANY AND LOCATION HAVE NOT BEEN MENTIONED.**

**I REQUEST YOU TO PLEASE FILL IN THAT INFORMATION AS WELL,
AS I NEED TO ANALYZE THE DATA ACCORDING TO LOCATION AS
WELL TO CARRY OUT THE RESEARCH WORK.**

**THIS INFORMATION IS CONFIDENTIAL AND WILL NOT BE USED FOR
ANY OTHER PURPOSES!**

Please tick the correct answer after reading the description of the question

1) Please enter your details for reference purposes only

*Name of the Company

*Location

*2) In-order to drain the fuel out from the car there can be several options.

- i. The car could be lifted up and then equipment can be used to drain the fluids out.
- ii. The car could remain on the ground and the worker slides under the car and uses a bucket to collect the fluids from it.
- iii. If there's any other method please mention the details about it so that it can be considered

Current procedure

Figure 3.2: Online Survey Page 1 sent to Canadian Recyclers

/

***5) Draining of fuel (i.e. petrol and diesel) from the ELV's requires a specific technology or an equipment to drain them out efficiently. Considering the existing systems being implemented in UK, USA, Canada and other Asian countries following technologies have been developed.**

Drain: in this method the port outlet underneath the car is opened and the fluid is collected in a bucket or a container and transported into a bigger container afterwards.

Suction: in this method technologically advanced equipment is attached to the outlet of the fuel tank, and with the help of hoses and vacuum suction all the fuel is sucked out from the tank and transported directly to the big containers.

Drilling the tank: In this method a portable drilling machine is used. The drilling machine is placed under the car (after being lifted up) and a hole is drilled into the fuel tank and fuel is extracted out using hoses. In addition, filters can also be attached to the machine to purify the fuel being extracted.

Pouring the fluid: This is a manual method in which the fuel tank is removed from the bottom of the car. After it has been removed the fuel pump is carefully removed from the tank and the fuel is extracted by pouring the fuel into buckets/containers. After the containers are filled they are transported to the bigger containers.

Please specify the method used at your facility so that facility types can be determined to implement the characteristics of the beneficial facilities into the proposed solution.

Drain
 Suction
 Drilling the tank
 Pouring
 Other (Please Specify):

/

***6) Is there any special equipment being used for the fuel drainage process (for example SEDA machines)? If yes, please specify it's name :**

/

***7) After the successful drainage of the fluids it is very essential to find out the possible**

freeonlinesurveys.com/v1/renderSurvey.asp?sid=1c0c924ee05a1010246 3/5

4/27/12 Survey provided by FreeOnlineSurveys.com

Figure 3.3: Online Survey Page 3 sent to Canadian Recyclers

3.6.2 Questionnaire Validation

The questionnaire has been prepared through an extensive literature review and validated through peer review from academicians, and practitioners from the industry. The objective of the questionnaire was to confirm that responses were based on correct interpretation of the questions. The questionnaire feedback provided was very helpful in the preliminary efforts to assess the reliability of the data. However, the data gathered from the survey and plant visits was later on converted to statistical data. Further, Cronbach's Alpha coefficient was calculated for the fluids studied during the research study individually to validate the questionnaire.

3.6.3 Sampling and Data Collection

The questionnaire framed earlier provided a basis for the data to be collected from the concerned authorities in India and Canada.

3.6.3.1 Indian Data

Initially, the process started by visiting the scrap dealers in Chandigarh and Patiala. The visits allowed me to consider the basic functionalities to be considered such as worker safety issues, environmental hazards during their drainage process, and tools and equipment's used for the drainage of the fluids from the vehicles. It was observed that the dismantling procedure being followed in India is very unhygienic for the workers, pollutes the environment substantially and is a time-consuming process. However, new drainage methods from different vehicles were learned during these visits, which further allowed categorizing the different drainage methods.

In addition, automotive service centers were visited to observe techniques that are more advanced and study the equipment's used for the oils drainage on a daily basis. The visits to the service centers were made to most of the automotive manufacturers such as Maruti Suzuki, Honda, Toyota, Audi, Mercedes, BMW, Ford, Chevrolet etc. The data collected from the service centers was recorded on hard-copy questionnaire taken along during the plant visits. Furthermore, disposal issues of the used oils were also brought into attention and were taken into consideration. In addition, the transfer of fluids from the smaller drums to the huge tanks located outside the facility were observed to study in depth about the environmental and time efficiency issues .

The data gathered from the scrap dealers and automotive service centers has been compiled into an excel format as seen in Table 3.1. The table illustrates the various questions that were asked during the visits that have been categorized as follows:

- Fluid drainage procedure,
- Drainage time,
- Quantity of oil drained out,
- Frequency of oil change,
- Usage of the used oil,
- Manual/automatic method for drainage,
- Number of cars processed daily, and
- Number of working bays in a facility.

Table 3.1: Data collected from Indian Facilities

Location	Name of Company	Fluid	Fluid Evacuation				Drainage Time			Quantity drained out			Frequency of drainage			Usage of the fluids			Procedure		Technology for drainage			Cars Processed Daily					Number of working bays						
			Drain nut is opened while the car is lifted up into a long drum	Drain nut is opened while the car is lifted up into a pan	Drain nut is opened while car is on the ground into a pan	Suction by inserting a pipe into the outlet	10 mins or less	11 - 20 mins	21 - 30 mins	>30 mins	0-3.5 lt	3.6-7 lt	>7 lt	5000-10000 Km	10000-15000 Km	>15,000 Km	Reuse	Sell to a recycling facility	Flush it in the drain	Lift the vehicle on a lift	Slide under the car	Automated	Manual	Both	1 to 5	6 to 10	11 to 20	20 to 30	>30	1 to 4	5 to 8	> 8			
Chandigarh	Padam Motors	X	X						X			X				X			X							X									
Chandigarh	G.M. Motors	X	X					X				X			X	X		X		X								X							
Chandigarh	Joshi Tata	X		X				X					X			X		X		X						X									
Chandigarh	Bhagat Ford	X		X				X				X			X	X		X		X					X										
Chandigarh	Berkley Maruti	X	X					X				X			X	X		X		X						X							X		
Chandigarh	Harmony Honda	X	X					X				X			X	X		X		X						X							X		
Chandigarh	Charisma Hyundai	X	X					X				X			X	X		X		X						X									
Chandigarh	Audi Chandigarh	X				X				X		X			X		X		X		X			X											
Chandigarh	Globe Toyota	X	X					X				X			X	X		X		X						X									
Chandigarh	Joshi Mercedes	X				X				X		X			X					X					X										
Patiala	Hira Maruti	X		X				X				X			X		X		X		X					X									
Patiala	Scarp dealer near kapila sir	X			X			X				X			X		X		X		X				X										
Chandigarh	Krishna BMW	X	X					X				X			X	X		X		X					X										

3.6.3.2 Canadian Data

In-order to gather information from Canadian recycling facilities, questionnaire was uploaded online as previously seen in Figure 3.2 & Figure 3.3. The questionnaire link was emailed to more than 300 recycling organizations in Canada. Each questionnaire was sent personally to the respondent in which the user was requested to mention their company details, and answer the questions related to the study. This technique additionally offered the opportunity to gather information from outside India. A reminder with an additional copy of the questionnaire was again sent to all the non-respondents to the initial study. A total of 30 responses were received and recorded. The response of 30 recycling organizations was found to be reasonable for the research study. The sample size (ss) was calculated using the formula: (L. Naing, 2006)

$$ss = \frac{Z^2 \times (p) \times (1 - p)}{c^2}$$

The input data is as follows:

Z = Z value (e.g. 1.96 for 95% confidence level)	1.65
p = percentage picking a choice, expressed as decimal	90%
c = confidence interval, expressed as decimal	10%

The sample size was found to be 24.5. Correction for finite population was needed since the population size is known to be 300. By using the following formula:

$$newss = \frac{ss}{1 + \frac{ss - 1}{pop}}$$

The new sample size was calculated as 22.72, certainly less than the actual number of responses received. In-order to validate the responses received a visit to the Canadian Recycling facilities was also made during the semester. After receiving the approval from the Head of Mechanical Engineering Department, Thapar University to conduct research study in Canada, contact was made with Director of Automotive Recycling Organization in Ontario i.e. Mr. Steve Fletcher. The visits were made to most of the companies in Ontario who had filled the online questionnaire and the data obtained from the online questionnaire matched with the actual plant visits to the facilities. However, due to the distance and time-constraints not all of the Canadian companies in different provinces could be visited. As a result, visits were made to other recycling facilities in Ontario. One of the Canadian recycling facility visited processed approximately 60 cars/day while ensuring proper drainage methods and eliminating environmental hazards and improving worker safety. In total, 15 Canadian Recycling facilities were visited and information gathered was recorded on the questionnaire which was later on converted into an excel format as seen in Table 3.2.

The parameters considered for Indian data have been kept same while preparing the table for Canadian recyclers. However, after the visits from Canadian recyclers, usage of the fluids factor was added to the study and the required data was gathered by again visiting the Indian facilities. Therefore, an iterative approach was followed during the data collection phase of the research study to include all the relevant parameters of study.

The fluids that have been studied are: petrol/diesel, engine oil, gear oil and coolant. After the plant visits, patterns and similarities were discovered in terms of methods (manual or automatic) and facility configuration.

The three distinct input constructs that are likely to influence the technological capability objectives include:

- Fluid drainage procedure,
- Transfer of used oil from the drums to the large tanks outside the facility, and
- Number of working bays.

The output performance parameter based constructs comprise of the following parameters:

- Drainage time,
- Quantity of oil drained out, and
- Number of cars processed daily.

3.6.4 Research Methodology

In-order to analyze the gathered data the research methodologies that have been implemented in the research study involve statistical analysis followed by industrial engineering analysis and concluded by performing breakeven analysis. The statistical analysis has allowed to determine the relation between the key input and output parameters of the study and to illustrate a regression model for the automotive industry. The statistical analysis has been performed using SPSS Software (IBM SPSS Statistics V19.0) to predict the results. The descriptive and empirical statistical analysis has determined the relations between the key factors of the study.

Questionnaire reliability is one of the major issues that was considered for the research study. Reliability of the results obtained from the questionnaire should be high, indicating strong correlation between the answers to the same question over wide range of respondents. Cronbach's alpha coefficient value assesses the degree to which measure of the same concept are correlated. The reliability of items under each output parameter has been assessed by using Cronbach's alpha coefficient, as recommended for empirical research in research study.

3.6.4.1 Cronbach's Alpha

Cronbach's alpha is an index of reliability associated with the variation accounted for by the true score of the 'underlying construct'. Alpha coefficient ranges from 0 to 1 and may be used to describe the reliability of the factors extracted from the questionnaire. The higher the value of alpha, the more reliable the generated scale is. Cronbach's alpha coefficient (α) is defined as per the following equations.

$$\alpha = \frac{N}{N-1} \left(1 - \frac{\sum_{i=1}^N \sigma^2 y_i}{\sigma_x^2} \right)$$

Where:

N : \rightarrow is the number of components (items)

σ_x^2 : \rightarrow is the variance of the observed total test scores

σ_y^2 : \rightarrow is the variance of component i .

The commonly accepted values as a rule of thumb for describing internal consistency using Cronbach's alpha is shown in table 3.3.

Table 3.3: Cronbach's Alpha Values

Cronbach's Alpha Value	Internal consistency
$\alpha \geq 0.9$	Excellent
$0.9 > \alpha \geq 0.8$	Good
$0.8 > \alpha \geq 0.7$	Acceptable
$0.7 > \alpha \geq 0.6$	Questionable
$0.6 > \alpha \geq 0.5$	Poor
$0.9 > \alpha \geq 0.8$	Unacceptable

The data recorded was tabulated into statistical data by numbering the categorical options from 1 to 4 for each of the parameters considered. The responses from all the questions were analyzed using SPSS to calculate the reliability coefficient for the questions. The reliability coefficient validated the responses received from the survey and plant visits. Furthermore, descriptive and empirical statistical analysis have been executed to determine the relation between the key input and output parameters of the study and to illustrate a regression model for the automotive industry.

3.6.4.2 Correlation Analysis

The descriptive analysis in statistics involves the use of correlations that can further be sub-divided into bi-variate and partial correlations. In Bivariate correlations, the relationship between two variables is measured. The degree of relationship i.e. how closely they are related could be either positive or negative. The values lie in the range of +1 to -1. This number is the correlation coefficient obtained through SPSS. In addition, a zero value obtained indicates no relationship between the two variables.

However, the table 3.4 illustrates the significance of the correlation coefficient values obtained.

Table 3.4: Significance of Correlation Coefficients

Correlation Coefficient	Significance
0 – 0.30	Weak
.31— 0.60	Moderate
> 0.60	Strong

To compute the correlation coefficient for the two measured variables the following procedure was followed. The procedure below determines the correlation coefficient for drainage procedure and drainage time for the data collected.

Procedure:

1. On the menu bar of SPSS Data Editor Window, Click Analyze → Correlate → Bivariate
This opens the Bivariate correlations dialog box as seen in figure 3.4 consisting of the variables of the research study.

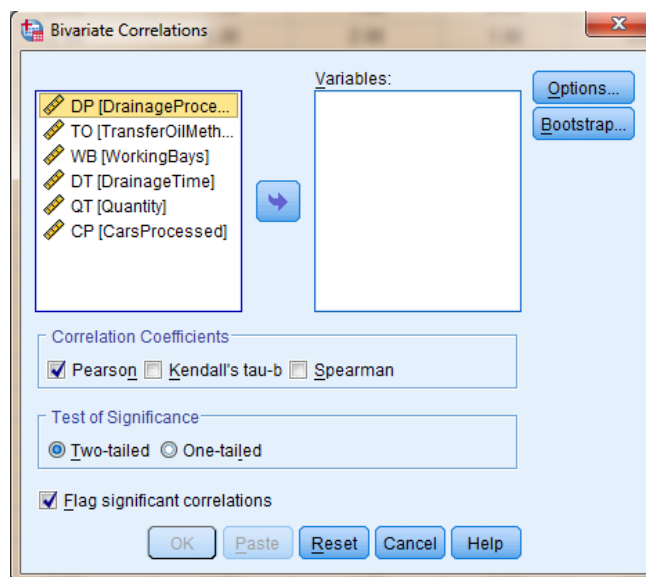


Figure 3.4: Bivariate Correlations Dialog box

2. Move the variables 'Drainage Procedure (DP)' and 'Drainage Time (DT)' to the variables box as depicted below in figure 3.5 by selecting and clicking on the right arrow button.

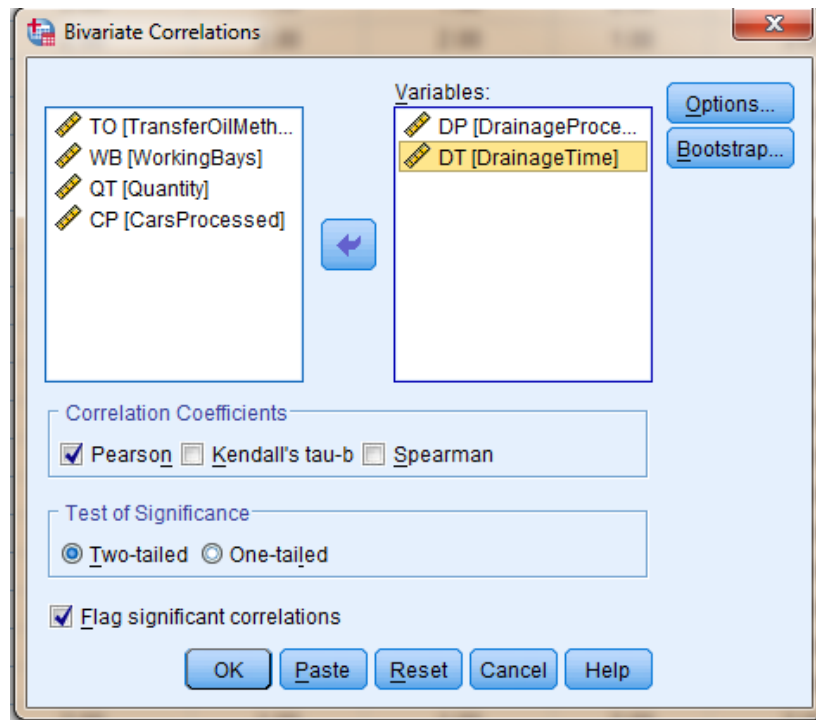


Figure 3.5: Selection of factors in Bivariate dialog box

3. Click on 'OK' to run the analysis. The output will be displayed in a separate SPSS viewer window.

The relationship between two variables may be consistent, increased, or decreased, when a third variable is taken into account. The results obtained in the bivariate analysis could have been affected by the other variables considered during the research study. Therefore, partial correlation analysis an extension of bi-variate correlation analysis has been performed to eliminate the effect of other variables on the two chosen variables.

The partial correlation procedure computes partial correlation coefficients that describe the linear relationship between two variables while controlling the effects of one or more additional variables. This methodology has been preferred over bi-variate correlation analysis since the effect of a parameter on the results of another parameter is not influenced and thus providing us with strong correlation significance among the two parameters considered.

However, different procedure is followed for the computation of partial correlation analysis as illustrated below. The procedure to carry out partial correlation analysis has been mentioned below by considering the dependent variables as drainage procedure and drainage time while controlling transfer of oil method variable.

Procedure:

1. On the menu bar of SPSS Data Editor Window, Click Analyze → Correlate → Partial
This opens the partial correlations dialog box consisting of the variables of the research study as showed in figure 3.6.

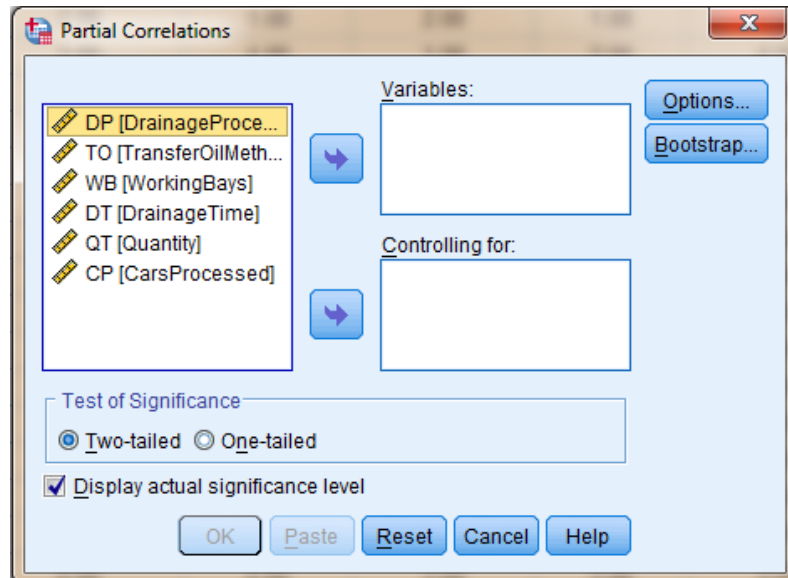


Figure 3.6: Partial Correlations Dialog box

2. Move the 'Drainage Procedure (DP)' and 'Drainage Time (DT)' variables to the variables box by selecting and clicking on the right arrow button as seen in figure 3.7. Select and move 'Transfer Oil Method (TO)' to the 'controlling for' box.

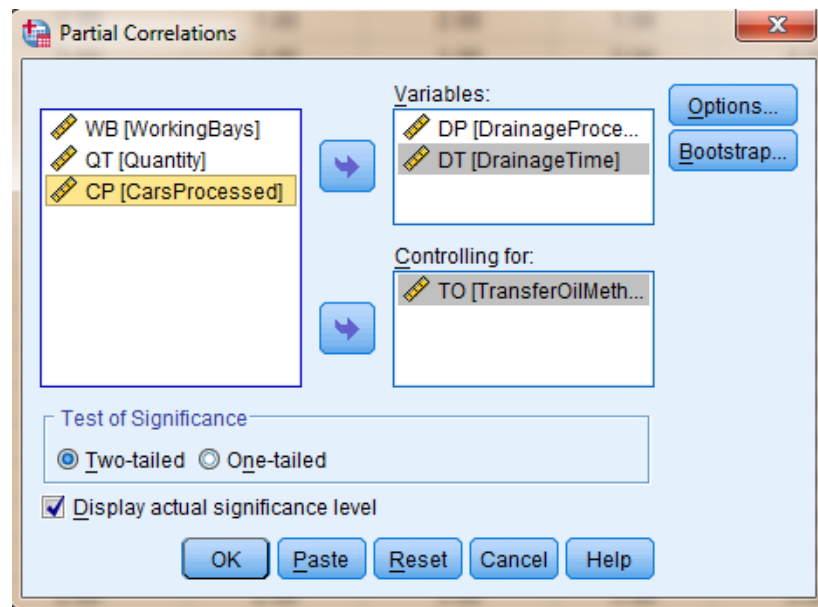


Figure 3.7: Selecting factors for partial correlations

3. Click on 'OK' to run the analysis. The output will be displayed in a separate SPSS viewer window.

SPSS lists the correlation coefficients it calculates in a correlation matrix. The values on the diagonal are all 1 because they represent the correlations of each variable with itself. The values above and below the diagonal are identical. Three pieces of information are provided in each cell – the correlation coefficient, the significance, and number of cases.

- The correlation coefficient obtained between drainage procedure and drainage time. It illustrates whether the correlation is strong/weak, or positive/negative between them.
- The significance of the data collected is determined by analyzing the significant value (p-value) obtained in the correlation matrix.
- The number of case (N) value indicates the total data available on which the correlation analysis has been performed using SPSS.

The correlation matrix obtained after performing partial correlation analysis lists ‘TO – transfer of oil method’ as a control variable on the left side of the table. It implies that the influence of controlled variable upon the drainage time and drainage procedure has been removed.

The correlation analysis has been executed for a two-tailed test while considering 95% confidence interval as illustrated in the procedure. The confidence interval provides a range of values within which it is likely that the true value lies. Commonly chosen confidence intervals are 90%, 95% and 99%. The 95% confidence interval has been chosen for this research study. The 95% confidence interval implies that if the sample population is sampled on numerous occasions and interval estimates are made on each occasion, the resulting intervals would bracket the true population parameter in approximately 95% of the cases. Thus, the probability of observing a value outside of the normal curve is less than 0.05. The p-value provides a measure of the strength of the variable considered along with an associated confidence interval. The P-values lie in the range of 0 and 1 being a probability. The p-value closer to zero indicates a stronger significant relationship between the factors considered. Hence, the statistical significance for the research study has been determined by observing if the calculated p-value (from SPSS output) is less than 0.05 or not.

The partial correlation has been performed between the input and output parameters such as drainage procedure and drainage time, drainage procedure and quantity of oil drained out while keeping factors such as number of cars processed, transfer of oil method, and number of working bays controlled.

Correlation coefficients obtained from SPSS varied from -1 to +1, with positive values indicating an increasing relationship and negative values indicating a decreasing relationship. It tells us that as one variable changes, the other seems to change in a predictable way. The formula for Pearson’s Correlation Coefficient is as follows:

$$r_{xy.z} = \frac{r_{xy} - r_{xz}r_{yz}}{\sqrt{(1 - r_{xz}^2)(1 - r_{yz}^2)}}$$

In the above equation, 'x, y & z' are the variables considered. The correlation has been determined between x and y while keeping the z factor as constant. The correlation coefficient value obtained from the formula lies in the range of -1.0 to +1.0.

A correlation coefficient of -1.00 tells that it is a perfect negative relationship between the two variables. This means that as values on one variable increase there is a perfectly predictable decrease in values on the other variable. Whereas, a correlation coefficient of +1.00 tells that there is a perfect positive relationship between the two variables. This means that as values on one variable increase there is a predictable increase in values on the other variable. A correlation coefficient of 0.00 tells that there is a zero correlation, or no relationship, between the two variables. This means that as one variable changes it cannot be predicted as to what happens to the other variable.

Correlation analysis is usually followed by regression analysis.

3.6.4.3 Regression Analysis

The main objective of the regression analysis is to explain the variation in one variable based on the variation in one or more independent variables. The empirical analysis uses regression tools such as linear regression, binary logistic, multinomial logistic and nonlinear regression on the data collected to determine the regression model for the data gathered.

If there is only one dependent variable and one independent variable used to explain the variation in it, then simple regression model is chosen. If there are multiple variables to explain the variation in a dependent variable, then a multiple regression model is chosen. The general regression model (linear) has the following equation:

$$Y = a + b_1X_1 + b_2X_2 + b_3X_3 + \dots + b_k X_k$$

Where y is the dependent variable and X_1, \dots, X_k are the independent variables expected to be related to y and expected to predict the values of y, b_1, b_2, \dots, b_k , that will be determined from the input data. The value of 'a' represents the intercepts of the linear regression model.

Procedure to perform linear regression is as follows:

1. Click Analyze → Regression → Linear from the SPSS menu bar
2. Linear regression dialog box will appear showing the variables on the left hand side of the box as seen in figure 3.8.

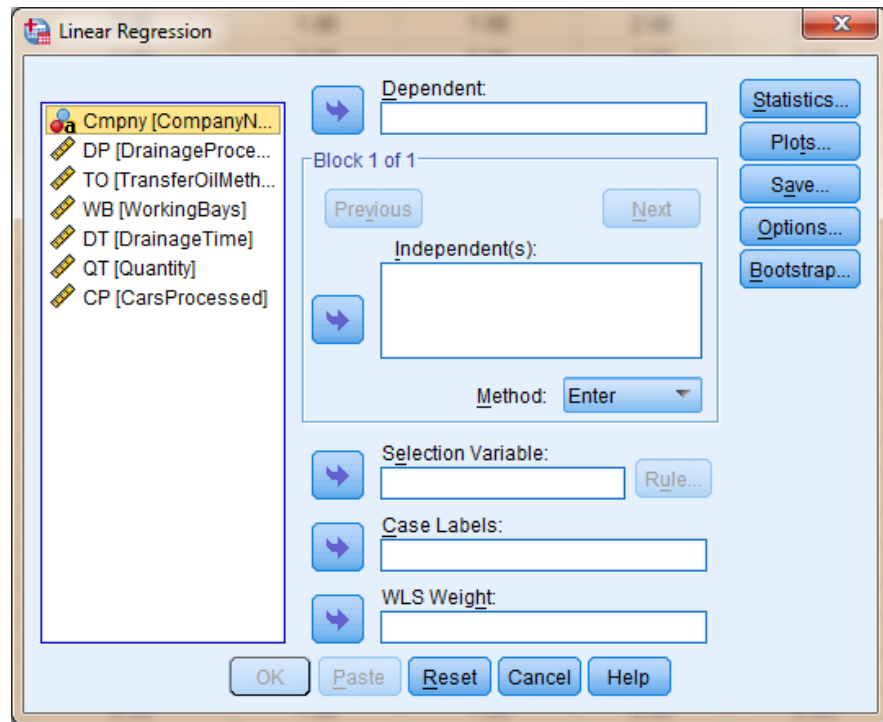


Figure 3.8: Linear Regression Dialog Box

3. The independent (predictor) variables of the study are selected and moved to the ‘Independent Box’ and the dependent (outcome) variable into the ‘Dependent Box’.
4. Further statistics options can be chosen from the ‘Statistics’ option on the right side of the dialog box.
5. Click ‘OK’ button to run the regression analysis on the input data. The output will be generated in a separate SPSS window.

The output window for regression analysis will include a ‘**Model Summary Table**’. This table provides the value of R and R^2 .

The R value → represents the simple correlation between the factors considered.

The R^2 value → can be manually calculated by taking the square of the r-values obtained. The values obtained are all positive and lie in the range of 0 (no correlation) and 1 (perfect correlation). It provides a measure to predict the future outcomes for the model.

The r-squared value is also known as the ‘Coefficient of Determination’. It tells about how well the regression line approximates the real data points. The higher the r-squared value, the better the model is fit.

Another table that displays significant results are in ‘**Coefficients Table**’. This table provides information on each predictor variable. It displays the significance of independent variables on the dependent variable by observing the ‘**Significance**’ column in the table. In addition, by looking at

the '**B column**' it represents the value of the intercept, and b-values for the independent variables. The residual value obtained after the regression analysis is a measure of the amount of variation that has not been taken into account by the regression equation and is listed as intercept in the B column. The values obtained from the analysis are entered into the general regression equation to determine the linear regression equation for the model.

The linear regression model is not applicable to the data collected since the data gathered and tabulated is categorical data rather than numerical data required for linear regression analysis. As a result, logistic regression analysis is considered to provide better statistical analysis for categorical data.

Logistic regression is used for situations where we want to predict the presence or absence of a characteristic or outcome based on values of a set of predictor variables. It is similar to a linear regression model but is suited to models where the dependent variable is dichotomous. Binary logistic regression analysis is used to determine the probability for categorical response variables with two outcomes. Therefore, the advantage of using a logistic regression methodology is to extend the linear regression model by linking the range of real numbers to the 0-1 range. The regression coefficients are estimated through an iterative maximum likelihood method. The limitation of binary logistic methodology is that it can be used to obtain a regression equation for the variable with two categories of the factor considered. Whereas, the data tabulated for engine oil, gear oil, coolant oil contain four categories under each of the key input and output parameters. As a result, the multinomial logistic regression methodology is the only regression tool that can be applied to the data for this research study.

The results obtained from the partial correlation analysis define the correlation among the input and output factors considered. In order to predict the future outcomes of the research study based on the key input and output factors considered regression analysis has to be performed. Hence, for closer examination of relationships between individual dimensions of dependent variable with the independent variables, the multinomial logistic regression analysis has been done.

Multinomial logistic regression methodology is used in situations in which the parameters can be classified based on values of a set of predictor variables. This methodology is similar to binary logistic regression, but is more general because the dependent variable is not restricted to two categories.

The research study carried out consist of categorical data i.e. the variables considered have each been sub-divided into four categories during the data collection process. For example, the variable drainage procedure variable has been further divided into 4 sub-categories as:

- Drain nut is opened while the car is lifted up into a pan (1),

- Drain nut is opened while the car is lifted up into a long drum (2),
- Drill a hole into the reservoir to drain the oil (3), and
- Suction by inserting a pipe into the oil container (4).

The value in the bracket indicates the respective number assigned to each drainage procedure. Depending upon the process chosen by the 31 companies the numbers have been entered in SPSS input sheet to perform the analysis. Similarly, the other factors have also been categorized into 4 categories.

The general multinomial logistic regression equation is as follows:

$$Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \dots + \beta_k X_k$$

The procedure to perform regression analysis has been illustrated by determining the relationship between the number of cars processed daily and its determinants, the number of cars processed has been taken as dependent variable and drainage procedure, transfer of oil method and number of working bays as independent variables.

The procedure followed to perform the analysis is as follows:

1. On the menu bar of SPSS Editor Window, click Analyze → Regression → Multinomial Logistic

This will open the multinomial logistic regression window as seen in figure 3.9.

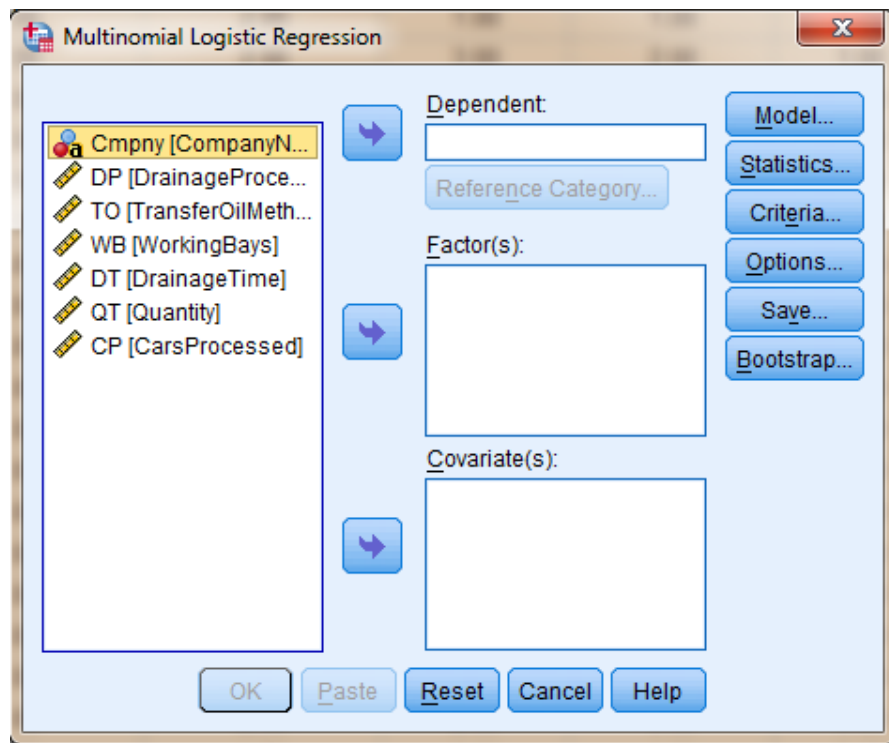


Figure 3.9: Multinomial Logistic Regression Dialog Box

2. Choose dependent variable i.e. 'Cars Processed (CP)' and move to the 'Dependent box' as seen in figure 3.10.
3. Now choose the independent variables i.e. 'Drainage Procedure (DP), Transfer of Oil Method (TO), and Number of Working Bays (WB)' and transfer them to the 'Factor(s) Box' as illustrated in the figure 3.10.

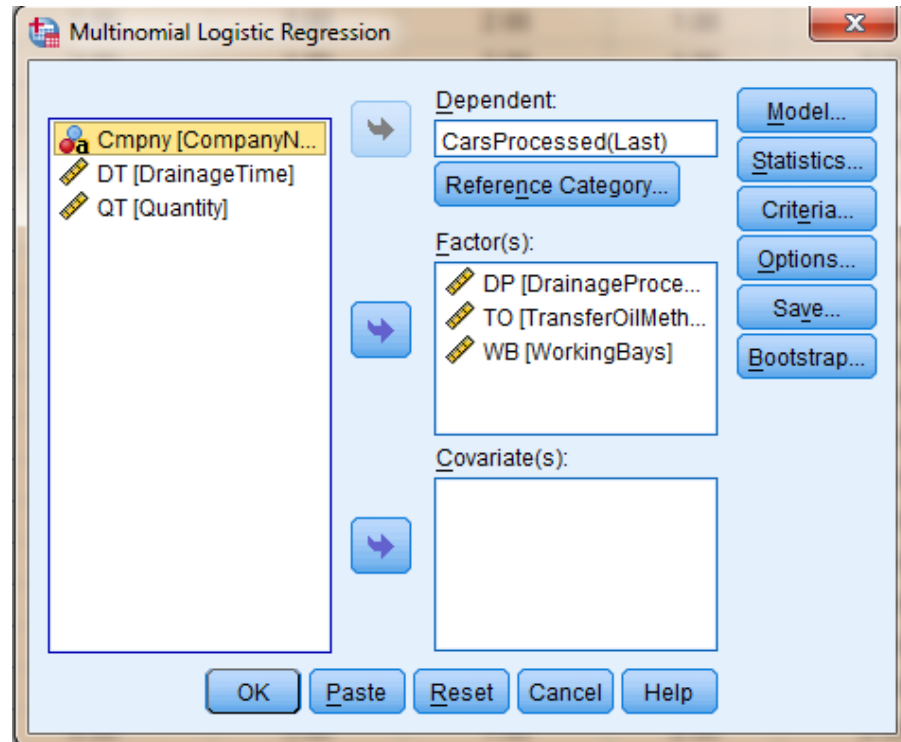


Figure 3.10: Selecting factors for multinomial regression analysis

4. Click on 'Statistics' button to choose the further regression statistics options as shown in figure 3.11 and ensure the options are chosen as selected below in the screenshot. This dialog box allows changing the confidence interval level for the analysis. After selecting the 'Information Criteria' option in the dialog box, it displays the beta values and the intercept value for the regression model.
5. Click on 'OK' button to run the regression analysis on the input data. The output window displays three different tables consisting of frequency table, Pseudo-R square table and Likelihood Ratio Tests table.

The tables that provide significant information to interpret the results are:

- Pseudo R-Square, and
- Likelihood Ratio Tests.

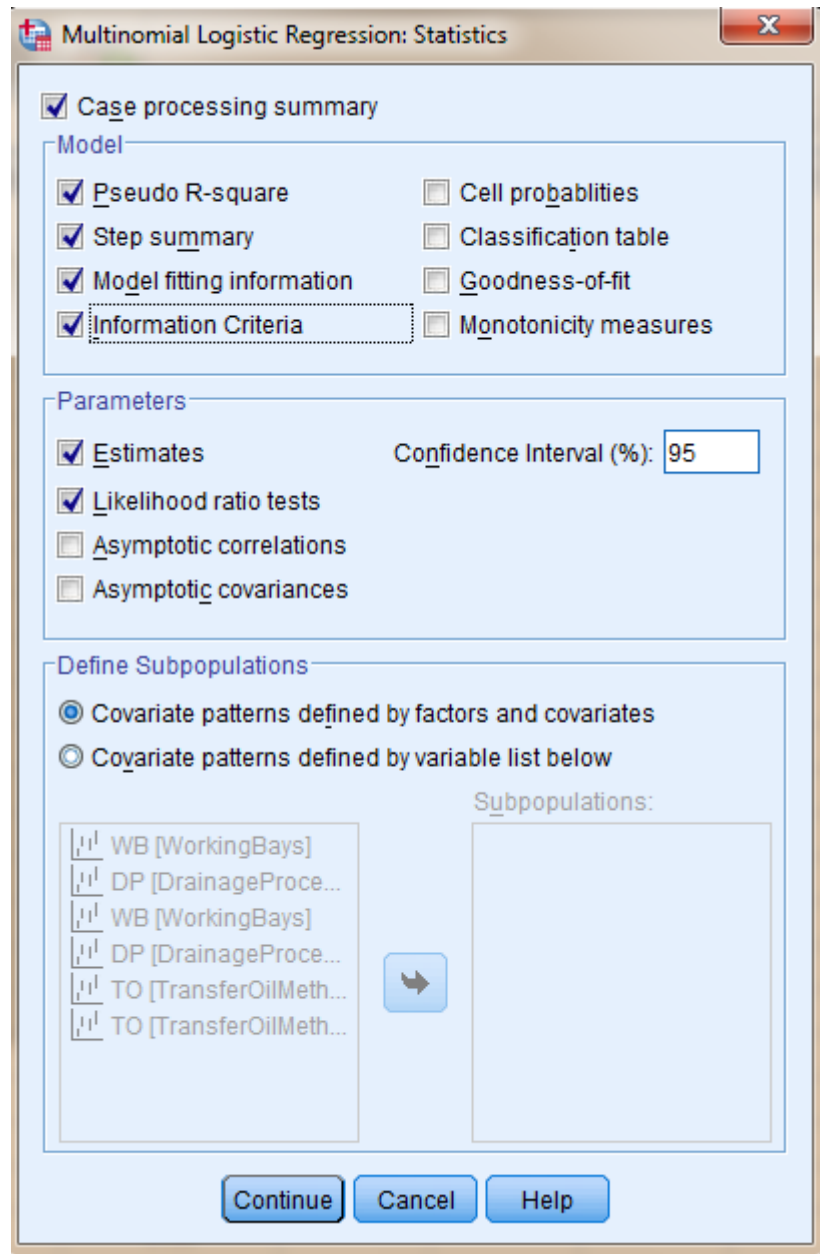


Figure 3.11: Statistics option in multinomial logistic regression analysis

The frequency table obtained illustrates the frequency distribution of the four categories for the dependent and independent variables obtained from the respondents of the survey and plant visits.

The Pseudo R-Square table illustrates the R-squared value obtained for the regression model. Three different types of R-squared values are obtained, however the commonly used is Cox and Snell R-squared value. The r-squared value obtained is statistically named ‘Coefficient of Determination’. The r-square value obtained illustrates the goodness-of-fit of regression equation. It has a value between 0 and 1 and higher the value of r-square, higher is the goodness of fit.

The Likelihood Ratio Tests table depicts the values of intercepts, and beta values of the multinomial regression model.

In conclusion, the statistical analysis has allowed to determine the significant relationships between the input and output factors related to the automotive fluids drainage from end-of-life vehicles. The next stage involves determining using industrial engineering tools the actual tasks performed by the worker including operation, transportation, storage, delay tasks during the drainage process of fluids from ELVs. In-order to assess the procedural effects on the objectives of the research study, flow process charts have been considered to analyze the tasks performed by the worker.

3.6.4.4 Flow Process Charts

Flow process charts are graphical and symbolic representations of work performed. Flow Process charts are widely used in industry to represent the entire sequence of a process. Flow Process Charts can follow the material being created or manufactured, or the worker performing the tasks. Due to the nature of the manual operations in the study, the operations performed by the worker were observed and documented. Flow process charts have been prepared for different facilities visited while categorizing them into three different facility types depending on the drainage procedure. As a result, all the information gathered was put together to develop three facility type value stream maps. These maps provide information about the stages the vehicle passes through before it is shredded as scrap. Some of the different tasks performed by the worker during the drainage procedure of petrol/diesel from the vehicles are:

- Operation tasks,
- Transportation tasks,
- Inspection tasks,
- Delay tasks, and
- Storage tasks.

The information from the survey and plant visits helped us understand in depth the different methods of petrol drainage i.e. automatic or manual. Moreover, it was observed from the plant visits and survey that facilities were configured in two ways as:

- One bay for fluid drainage followed by several dismantling bays for other parts of the vehicle, and
- Fluid drainage and dismantling of all the parts at the same bay.

Each of the flow charts prepared illustrate the different procedure for the drainage of petrol/diesel from ELVs. It involves the time required by the worker to gather tools, buckets, removing of the fuel tank from the vehicle and other relevant steps studied during the data collection phase of the research study. The flow process charts allowed to consider the several factors which have

substantial impact on the outcomes of the drainage process of petrol/diesel from a vehicle. Therefore, a methodology that could consider the potential reasons and finally suggest a recommendation was found out after performing an extensive literature review. The literature review illustrated the use of Failure Mode Effect Analysis (FMEA) that provides an organized, critical analysis of potential failure modes of the system being defined and identifies associated causes along with recommendations to improve the current process.

3.6.4.5 Failure Mode and Effect Analysis (FMEA)

Failure modes and effect analysis (FMEA) is an established reliability engineering activity that supports fault tolerant design, testability, safety, logistic support, and related functions. The purpose of FMEA is to analyze the design characteristics relative to the planned manufacturing process to ensure that the resultant product meets customer needs and expectations. After the potential failure modes have been identified, corrective actions are taken to eliminate or continually reduce the potential for occurrence. This tool was used to analyze the impact of environment and ergonomic issues of the current practices for petrol/diesel drainage that facilities are following. The RPN is calculated by multiplying the severity (1-10), occurrence (1-10) and detection ranking (1-10) levels resulting in a scale from 1 to 1000.

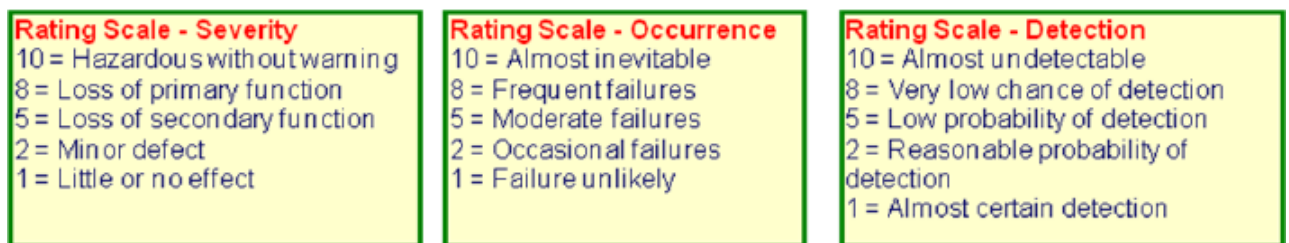


Figure 3.12: FMEA Rating Scale

The figure 3.12 shown above illustrates the rating scale for the severity, occurrence and detection used for the calculation of RPN value in the FMEA analysis.

After the FMEA analysis has been performed the RPN values were analyzed carefully to determine the potential factors that posed a major concern for the drainage procedure of petrol/diesel on the environment and the safety of the worker. The FMEA analysis helped to determine the important factors in a drainage process that were improved and implemented into the proposed drainage method.

The last stage of the research study involves the validation of the proposed methodology. For the purposes of validation, the literature review suggested to carry out decision matrix method also known as Pugh analysis. The Pugh Matrix is a type of matrix diagram that allows for the comparison of a number of design candidates leading ultimately to the best design that meets the objectives of the research study. For the purposes of this research study, the three existing facility

configurations were compared with the proposed facility type that encompasses the outcomes of statistical analysis, flow process charts and FMEA analysis.

3.6.4.6 Decision Matrix

The Pugh Matrix also known as Pugh analysis, decision matrix method, selection matrix, problem matrix, criteria based matrix in industry. Being a decision making model, it is used to choose between a list of alternatives. The Pugh Matrix is a type of matrix diagram that allows for the comparison of a number of design candidates leading ultimately to which best meets a set of criteria. In constructing a Pugh Matrix, one design concept, was selected as the ‘baseline’. The other design concepts were then compared in a pair wise fashion against the baseline for each of the criteria. The ranking in the matrix was done on the following basis:

- Better than the baseline a “+” is entered into the appropriate cell,
- Worse than the baseline a “—” is entered into the appropriate cell, and
- Same than the baseline a “s” is entered in the appropriate cell.

The overall evaluation was made by adding the “+” and “-” for each design concept. The ‘best’ approach was selected based on the consolidated scores. This method has been used for the research study to compare the proposed method for the petrol/diesel drainage against the other facility types to meet the objectives of the research study.

3.6.4.7 Break-Even Analysis

A break-even analysis shows the relationship between the costs and profits with sales volume. The sales volume, which equates total revenue with related costs and results in neither profit nor loss, is called the break-even point. The costs considered are fixed and variable costs.

The costs, which remain fixed irrespective of the level of output, are called fixed costs. The total fixed cost (TFC) includes the following equipments required for the drainage process of automotive fluids from ELVs:

- Lift used to lift a vehicle,
- Type of pump used to transfer petrol/diesel directly to storage tank from the vehicle,
- Suction pump to transfer oils (i.e. engine, gear and brake oil),
- Suction pump to transfer coolant,
- Drill/punch to drain out petrol/diesel from the fuel tank,
- Funnel set to collect the oils from the vehicle,

- Huge storage tank located outside the facility to collect petrol/diesel, used oils and coolant,
- Control box with levers for different fluids, and
- Piping used for the safe transfer of fluids from the vehicle to the storage tank outside.

Variable costs are those costs, which vary with the level of output. The total variable costs (TVC) include the costs of electricity consumption and labor charges.

Total Cost (TC) is the sum of total fixed costs and total variable costs.

$$TC = TFC + TVC$$

The total fixed cost is constant, but total variable cost increases as number of day's increases, so total cost also increases as number of day's increases. The TC curve is a rising curve and the vertical distance between TVC and TC curve, for any number of days is same and is equal to TFC as seen in the figure below.

Total Revenue (TR) is the revenue generated after the drainage process has been performed on the vehicle and calculated by considering the following parameters:

- Quantity of petrol and diesel obtained from a vehicle,
- Quantity of used oil collected,
- Quantity of coolant fluid collected,
- Cost of petrol and diesel (per litre),
- Price of used oil (per litre), and
- Number of cars that can be processed daily.

Therefore, Total Revenue (TR) has been calculated using the following formula:

TR (Petrol Vehicle) = [(Qty. of Petrol drained x Cost of petrol/ltr) + (Qty. of oil drained x price of used oil/ltr)] x No. of cars processed daily

TR (Diesel Vehicle) = [(Qty. of Diesel drained x Cost of diesel/ltr) + (Qty. of oil drained x price of used oil/ltr)] x No. of cars processed daily

The mathematical equation for calculating the break-even point (BEP) (in days) is as follows:

$$BEP = \frac{TFC}{TR - TVC}$$

The graphical representation of break-even analysis is shown in figure 3.13.

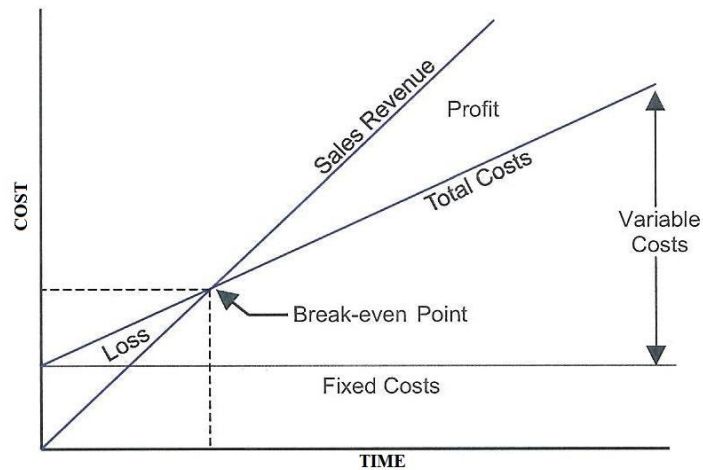


Figure 3.13: Breakeven Analysis representation

The sales revenue curve originates from zero since total revenue is zero even when there is no drainage process occurring. However, the fixed cost is required even when the cars are not being processed. The total cost is more than revenue until the intersection point of the two lines. The intersection point is referred to as the break-even point where the company is making neither profit nor loss. As the number of days increases beyond the break-even point, the sales revenue curve rises above the total costs curve and the gap between the two goes on increasing. This widening of the gap between the two curves indicates total profits of the company.

In-order to accomplish the objective of proposing a drainage process that is cost-effective, break-even analysis has been executed. This analysis has been performed for both petrol and diesel vehicles studied during the information gathering phase of the research study. The results of the break-even point illustrate the minimum number of days required by the company to process the vehicles in order to prevent the losses.

3.7 Chapter Summary

The methodology adopted for the study along with the step-by-step approach employed for the research has been elaborated in this chapter. Descriptive analysis and multinomial logistic regression analysis have been performed to depict the statistical significance between the factors considered along with the results from industrial tools for the drainage procedures of automotive fluids presently being followed. The decision matrix and break-even analysis validates the proposed drainage procedure of automotive fluids from the vehicles. Lastly, the breakeven analysis determines the point at which cost or expenses and revenue are equal i.e. there is not net loss or net gain for the company to carry out the process.

CHAPTER 4. ANALYSIS OF RESEARCH

4.1 General

This chapter presents the analysis and major findings of survey based research data. The survey explores the current practices of automotive fluids drainage from ELVs and resulting performance improvements in the automotive sector in India. The main factors affecting the performance of Indian recycling industry have been evaluated. The analysis also establishes the relationship of key input factors with output performance parameters.

4.2 Response to the Survey

Out of 300 questionnaires sent, 30 responses were received from Canadian recyclers and visits were made to 31 facilities to collect and validate the data collected.

The country-wise response to survey by making visits to the facility as a percentage of total responses has been graphically represented using a pie-chart as seen in Appendix – III. From the total responses, received 58% of the responses were from Canada and rest was collected by visiting various service centers in India. Analysis of the data has been performed on the data collected by visiting the facilities. The facilities visited in India and Canada accounts for more than 50% of the total survey respondents received as illustrated in Appendix – III. Whereas, the other relevant data for the research study has been collected by e-mailing the online questionnaire to the Canadian Auto Recyclers. The information regarding the drainage of fluids from ELVs received from Canadian online survey was validated by personally visiting most of the recyclers. Actual visits to the facilities proved to be very knowledgeable and beneficial for the research study as it allowed to study the process steps in detail during the dismantling stage of the life cycle of a vehicle.

The responses from the survey and plant visits have been summarized in a tabular manner for the various oils i.e. engine oil, gear oil, coolant and petrol/diesel. The table tabulated has been organized in such a manner that it includes the significant input and output factors required to achieve the objectives of the research study. The data gathered from the survey respondents was transformed into four categories for each of the factors considered. The six important factors that have been categorized as input and output factors have been stated previously in Chapter 3 of the report.

The responses of survey show that four different drainage methods are being followed for various oils. The survey responses illustrate manual, semi-automatic and automatic methods for the drainage of the oils from end-of-life vehicles. The different drainage methods for each of the oils have been discussed in detail in the next sections.

4.3 Analysis of the Response

Firstly, the four different drainage methods of engine oil have been discussed in detail. These methods have further allowed us to analyze the effects of drainage methods on the output factors i.e. drainage time, quantity of oil drained out and the number of cars processed.

Table 4.1: Categorical Data for Analysis of Survey

Location	Name of Company	Fluid	Fluid Drainage Procedure				Transferring of used oil to the huge tanks/drums outside			Number of working bays				Drainage Time depending upon the procedure				Quantity drained out depending upon the procedure				No. of cars processed daily depending upon the procedure				Usage of the fluids					
			Drain nut is opened while the car is lifted up into a pan	Drain nut is opened while the car is lifted up into a long drum	Drill a hole into the reservoir to drain the oil	Suction by inserting a pipe into the oil container	None	Manual	Semi-automatic	Automatic	1 to 2	3 to 4	5 to 6	7 to 8	12 mins - 24 mins	9 - 22 mins	9 - 20 mins	8 mins - 22 mins	0 - 6 lt	0 - 6.5lt	0 - 7 lt	0 - 8 lt	1 to 10	1 to 12	1 to 20	16 to 40	Reuse	Sell to a recycling facility			
Chandigarh	Padam Motors	1		2				2				2			1				1				2					1	1		
Chandigarh	G.M. Motors	1		2				2				1			1				2				2					1	1		
Chandigarh	Joshi Tata	1	1					2					3		2				1					3				1	1		
Chandigarh	Bhagat Ford	1	1					2				1			2				1				2					1	1		
Chandigarh	Berkley Maruti	1		2				2					4		1				2					4			1	1			
Chandigarh	Harmony Honda	1		2					3				4		1				3					4				1	1		
Chandigarh	Charisma Hyundai	1		2				2					2		1				2					3				1	1		
Chandigarh	Audi Chandigarh	1				4			3				3				4			4				3				1	1		
Chandigarh	Globe Toyota	1		2					3				2		1				3					4				1	1		
Chandigarh	Joshi Mercedes	1				4			3				3				4			4				3				1	1		
Patiala	Hira Maruti	1	1					2					4		2				2					3				1	1		
Patiala, Chandigarh	Scarp dealers	1	1					2				1			2			1				1					1	1			
Chandigarh	Krishna BMW	1		2				2					2		1				2				2					1	1		
Kitchener	Loge's Auto Parts	1			3				3				1			3			3					3				1	1		
London	LKQ Shaw Auto Recyclers	1		2						4			2		1					4							4		1	1	
London	Andy's Auto Wreckers	1		2				2				1			1				2				2					1	1		
London	Corey's Auto Wreckers	1			3			2					4			3			3					3				1	1		
Mississauga	Cooksville Auto Recyclers	1		2				2				1			1				3				2					1	1		
Mississauga	Northqueen Auto Wreckers	1			3			2					2			3			3					3				1	1		
Courtice	Dom's Auto Parts	1		2						4				3	1					4				2				1	1		
Oshawa	Oshawa Auto Parts	1		2				2				1			1				2				2					1	1		
Ajax	Ajax Auto Wreckers	1				4				4			2			4			4					4				4		1	1
Aurora	Carcoon's Auto Recycling	1		2				2					4		1				2				2					1	1		
Aurora	Hilltop Auto Wreckers	1			3			2				1				3			2					3				1	1		
Cookstown	Cookstown Auto Center	1	1					2					2		2			1				1						1	1		
Markham	Standard Auto Wreckers	1				4				4			4				4		4					4				4		1	1
Oakville	Ontario Auto Salvage	1				4			3			1				4			4				4					4		1	1
Hamilton	Bodyline Auto Wreckers	1		2						4			1		1				3					2				1	1		
Leamington	A & L Auto Recyclers	1				4				4			2				4		4					4				4		1	1
Windsor	J & B Auto Recyclers	1		1				2				1			2			1		4				1				1	1		
Kitchener	Paeshi Motors	1	1					2				1			2			1				1						1	1		

Table 4.1 illustrates the snapshot of engine oil categorical data used for statistical analysis. The tabulated data was modified into categorical data by allotting the options from 1 to 4 for each of the parameter's considered for analysis of the data as seen in table 4.1. The categorical data was required for the purpose of statistical analysis in SPSS software since the data needed to be entered in a numerical form to obtain the results.

The other input parameters that are essential for the efficient drainage method are: the transfer oil method from tanks to the big drums located outside the facility and, the number of working bays in a facility have also been discussed. These methods are the outcomes of plant visits in India and Canada and the online survey conducted in Canada.

4.4 Engine Oil & Gear Oil

Engine oil and gear oil measures a crucial amount of oils in a vehicle, which needs to be drained out during the dismantling process of ELVs. The drainage methods have been found to be similar after analyzing the responses from the survey for both engine and gear (transmission) oils. Four different drainage methods have been obtained from the information-gathering phase of the research study in India and Canada, which is illustrated in the table 4.2 shown below:

Table 4.2: Engine Oil Categorical Data obtained from survey and facility visits

Location	Name of Company	Fluid	Fluid Drainage Procedure				Transferring of used oil to the huge tanks/drums outside				Number of working bays				Drainage Time depending upon the procedure				Quantity drained out depending upon the procedure				No. of cars processed daily depending upon the procedure				Usage of the fluids	
			Drain nut is opened while the car is lifted up into a pan	Drain nut is opened while the car is lifted up into a long drum	Drill a hole into the reservoir to drain the oil	Suction by inserting a pipe into the oil container	None	Manual	Semi-automatic	Automatic	1 to 2	3 to 4	5 to 6	7 to 8	12 mins - 24 mins	9 - 22 mins	9 - 20 mins	8 mins - 22 mins	0 - 6 lt	0 - 6.5lt	0 - 7 lt	0 - 8 lt	1 to 10	1 to 12	1 to 20	16 to 40	Reuse	Sell to a recycling facility
Chandigarh	Padam Motors	1	2				2					2			1			1				2					1	1
Chandigarh	G.M. Motors	1	2					2				1			1			2				2					1	1
Chandigarh	Joshi Tata	1	1					2						3			2							3				1
Chandigarh	Bhagat Ford	1	1					2				1				2		1				2						1
Chandigarh	Berkley Maruti	1	2					2						4	1			2						4			1	1
Chandigarh	Harmony Honda	1	2						3					4	1				3					4				1
Chandigarh	Charisma Hyundai	1	2					2						2	1			2					3					1
Chandigarh	Audi Chandigarh	1			4				3					3			4			4			3					1
Chandigarh	Globe Toyota	1	2						3					2					3					4				1
Chandigarh	Joshi Mercedes	1			4				3					3			4			4			3					1
Patiala	Hira Maruti	1	1					2						4			2			2			3					1
Patiala, Chandigarh	Scarp dealers	1	1					2				1				2		1				1					1	1
Chandigarh	Krishna BMW	1	2					2						2	1			2				2						1
Kitchener	Logel's Auto Parts	1			3				3			1				3			3				3					1
London	LKQ Shaw Auto Recyclers	1	2						4					2	1				4					4				1
London	Andy's Auto Wreckers	1	2					2				1			1			2				2						1
London	Corey's Auto Wreckers	1			3			2						4			3		3				3					1
Mississauga	Cooksville Auto Recyclers	1	2					2				1			1			3					2					1
Mississauga	Northqueen Auto Wreckers	1			3			2						2			3		3				3					1
Courtoice	Dom's Auto Parts	1	2						4					3	1				4				2					1
Oshawa	Oshawa Auto Parts	1	2					2				1			1			2				2						1
Ajax	Ajax Auto Wreckers	1			4				4					2			4		4				4					1
Aurora	Carcoon's Auto Recycling	1	2					2						4	1			2				2						1
Aurora	Hillop Auto Wreckers	1			3			2				1				3		2					3					1
Cookstown	Cookstown Auto Center	1	1					2						2			2		1			1						1
Markham	Standard Auto Wreckers	1			4				4					4			4		4				4					1
Oakville	Ontario Auto Salvage	1			4				3			1				4		4				4						1
Hamilton	Bodyline Auto Wreckers	1	2						4			1			1			3				2						1
Leamington	A & L Auto Recyclers	1			4				4					2			4		4				4					1
Windsor	J & B Auto Recyclers	1	1					2						1			2		1			1						1
Kitchener	Plaeshi Motors	1	1					2				1					2		1			1						1

Table 4.2 lists the data obtained after visiting in total 31 facilities (in both India and Canada). The first column illustrates the location of the company and the adjoining column lists the name of the company. The next column displays the type of fluid being studied at each of the companies. The next set of tabulated data has been categorized into six broad categories where each of these categories has been further sub-divided into four sub-categories. The first three categories i.e. fluid drainage procedure, transfer of oil method, and number of working bays are the independent factors of the research study. The independent factors are followed by the output categories i.e. drainage

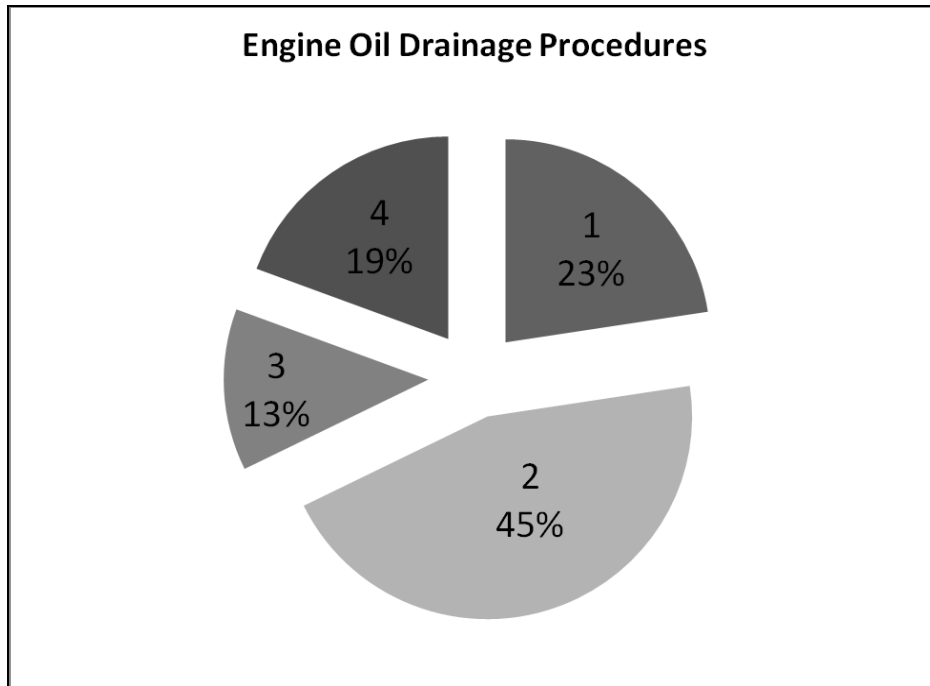


Figure 4.1: Engine Oil Drainage Procedures

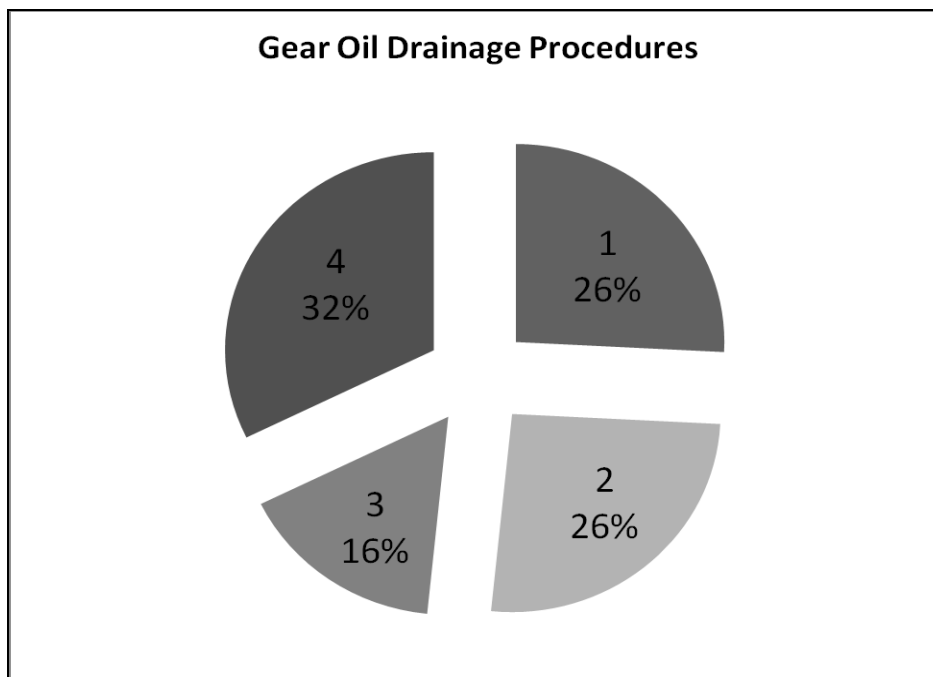


Figure 4.2: Gear Oil Drainage Procedures

Figure 4.1 and 4.2 illustrate the proportion of four different drainage procedures for engine and gear oil respectively followed by the 31 companies visited. The drainage procedure of opening the drain nut while the car is lifted up and collected in a pan is followed by 23% of the total companies for engine oil in comparison to 26% for gear oil. The pie charts have allowed to compare the different drainage methods being followed by the companies for the engine and gear oil. The four drainage method have been discussed in detail below.

I. Drain nut is opened while the car is lifted up into a pan:

This method involves firstly lifting the vehicle using jacks or appropriate ramps to raise the vehicle up to a certain height such that the workers can have access to underneath the vehicle without causing any neck injury. Following that, the worker identifies the engine oil and gear oil drain plugs located at the lowest level of the engine and transmission oil chambers. After the drain plugs are found, the worker positions the oil catch pan under the engine oil drain plug, drain plug is then opened using a wrench, the oil cap is removed to expedite the draining process, and the engine oil is drained out. Meanwhile, the oil filter was also removed located near the engine oil chamber for disposal purposes. Hence, after all the engine oil was drained out the drain plug was re-installed. After the engine oil has been completely removed out the worker opens the gear oil drain plug, places the pan underneath the vehicle, drains out the oil completely. The drainage process of gear oil is performed simultaneously occasionally in the vehicles if the drain plugs are located quite closely.

The drainage procedure of engine oil has been followed by the small-scale facilities in India, Canada, and accounts for 23% of the survey responses as seen in figure 4.1. On the other hand, 26% of the companies have been using this method for the drainage of gear oil from ELVs as seen in figure 4.2.



Figure 4.3: Engine Oil Drainage Method 1

The figure 4.3 demonstrates the manual drainage methods for engine oil. During the method spillages occurred on the floor and it was observed that this method on average required more time than the other three drainage methods studied.



Figure 4.4: Gear Oil Drainage Method 1

Figure 4.4 depicts the location of the gear oil nut underneath the vehicle and the pan used for the collection of the used gear oil from the vehicle during its drainage process.

II. Drain nut is opened while the car is lifted up into a long drum

In this method as well, the vehicle is initially lifted upon a lift to allow access to underneath the vehicle. The engine and gear oils are usually drained out from drain plugs after locating the respective oil chambers in a vehicle in both India and Canada. Depending on the make, model of the vehicle location of the oil drain plugs varied from vehicle to vehicle. The worker then accessed the portable drum with a funnel on the top to collect the used oil. The height of the funnel is adjustable and the drum located underneath has a capacity of approximately 30 litres. After the drain plug are removed, the funnel is adjusted, to collect the maximum oil while trying to minimize the oil spillages on the floor.

This method has been more widely preferred for engine oil as it accounts for 45% of the total survey responses in comparison to 26% for gear oil drainage in both India and Canada. Moreover, the portable trolley provides easy and faster access to the collecting equipment thus improving the time-efficiency of the workers.

Figure 4.5, illustrates the long drum used for the drainage of the engine oil and gear oil in India and Canada. It was observed that the two oils were collected in the same collecting drum usually as they both are being sold as ‘used oils’ to the recycling companies. The figure on the left is one of the collecting drums used widely in India. On the other hand, the figure on the right depicts the useful drums and pans required for the used oil collection during the drainage process. The items have been placed at an appropriate location to allow easy accessibility to the workers and to keep the floor area safe and clean from the spillages. Additionally, the drums observed in Canada have a nozzle located at the bottom of the long drums to transfer out the oil semi-automatically from the

long drum to the huge storage tanks located outside. The transfer of the oil methods from drum to the storage tanks outside has been discussed in detail in the next section.



Figure 4.5: Engine and Gear Oil Drainage Method 2 – India and Canada

III. Drill a hole into the reservoir to drain the oil



Figure 4.6: Engine Oil drainage Method - 3

In this method, the vehicle is again lifted up and the worker accesses engine oil and gear oil chamber underneath. This method is preferred mostly on the accidental vehicles or the vehicles in which the manufacturer does not design the drain plug. It was observed from the accidental cars that if the front portion of the vehicle is badly damaged it was very hard for the worker to open the drain plug to drain out the oils. To overcome the situation the worker operates on the oil chambers using a pneumatic drill, drills a small hole into the chamber, and collects the oil into the long drum with a funnel on the top. As observed in Figure 4.1, a small portion i.e. 13% of the total responses has implemented this procedure for the drainage of the engine oil from the ELVs. Whereas, better response to this method has been observed for the gear oil drainage that is 16%. Additionally, the 13% and 16% contributions are only from the Canadian recyclers and none from India. Though this process is little better than the earlier method, even then it is not widely used in the automotive industry. One of the advantages of this method is that worker does not have to spend extra time to locate the drain plug in a vehicle, and can immediately start draining

the used oil after drilling a hole into the oil chambers.

IV. Suction by inserting a pipe into the oil container

This drainage method involves the use of pneumatic suction equipment to drain out the used oil from the ELVs. The suction equipment could be either manual or automatic. The one end of the suction hose is inserted into the ‘dip stick’ of the engine oil-collecting chamber in a vehicle and oil is drained out. In a manual suction method, the worker creates a suction by pressing the lever up and down repeatedly and the oil is drained out. It’s a highly time consuming process and involves lot of hard-work by the worker operating the equipment. In contrast, the automatic suction system uses air pressure to create suction, the hose is inserted into the dipstick, and after the suction is created, the used oil is drained out in a time-efficient manner into a container. Additionally, no spillages occur during this drainage method and more cars are processed in the same time.

This method accounts for 19% and 32% of the total responses from the survey for engine oil and gear oil respectively both in India and in Canada as seen in figure 4.1 and 4.2. The suction method has been more preferred for the gear oil drainage in comparison to other three methods discussed earlier. AUDI in India has mechanical suction equipment with a funnel on the top of the drum and is connected to an air pump to carry out the drainage process of the gear oil from their vehicles.



Figure 4.7: Engine and Gear Oil Drainage Method - 4

The figure 4.7 depicts the two suction equipment’s used in the automotive recycling industry for the drainage purposes. The figure on the left is cost-effective equipment and environmentally friendly technique for the drainage of the used oil but is a time-consuming process as constant suction pressure needs to be maintained by the worker to suck out all the oil from the engine oil and gear oil chamber. If there is a difference in pressure, the oil would stop being drained out and

suction pressure would need to be created again by the worker. However, to maximize the oil drainage from the vehicle, automatic suction equipment has been used. As seen in the Figure 4.7, the equipment on the right-side has a capacity of 40 litres and is equipped with different sizes of hoses to be inserted into the dipstick of engine and gear oil. A suction valve is located on the other end and is connected to an pneumatic pump and after the valve is opened, the used oil is drained out completely in a few minutes.

Hence, four different methods/procedures were observed during the plant visits and survey. This information along with the advantages/disadvantages of each of the methods discussed earlier have been noted down to perform analysis to determine the most preferred method out of them. The proposed solution would comprise of the best features required for the drainage of the engine and gear oil while accomplishing the objectives of the research study.

Along with the fluid drainage procedure, one of the other input factors that are relevant is the method of transferring used oil from the drums/pans to the huge storage tanks located outside the facility. After the oil is collected in the drums, they are transferred to the huge tanks approximately 3000 litres and are then sent to the recycling facilities for the recycling purposes. The section 4.6 discusses in detail the transfer methods of the fluids from the drums to the storage tanks outside the facility.

4.5 Coolant

Coolant is a fluid which flows through a device to prevent its overheating, transferring the heat produced by the device to other devices that use or dissipate it. The coolant used in vehicles has high thermal capacity, low viscosity, and non-toxic. However, the coolant is mixed with additives such as antifreeze. Antifreeze, a solution of a suitable organic chemical mostly ethylene glycol is mixed with water to withstand temperatures below zero degree Celsius or to raise its boiling point. The removal of coolant from the vehicles followed the similar principle and procedures as of the other oils mentioned earlier. From the responses of the survey and plant visits, four different methods found are as follows:

- I. Drain nut is opened while the car is lifted up into a pan
- II. Hose is opened/cut while the car is lifted up into a pan/long drum
- III. Suction by inserting a pipe into the radiator cap
- IV. Suction by piercing the radiator hose – automatic

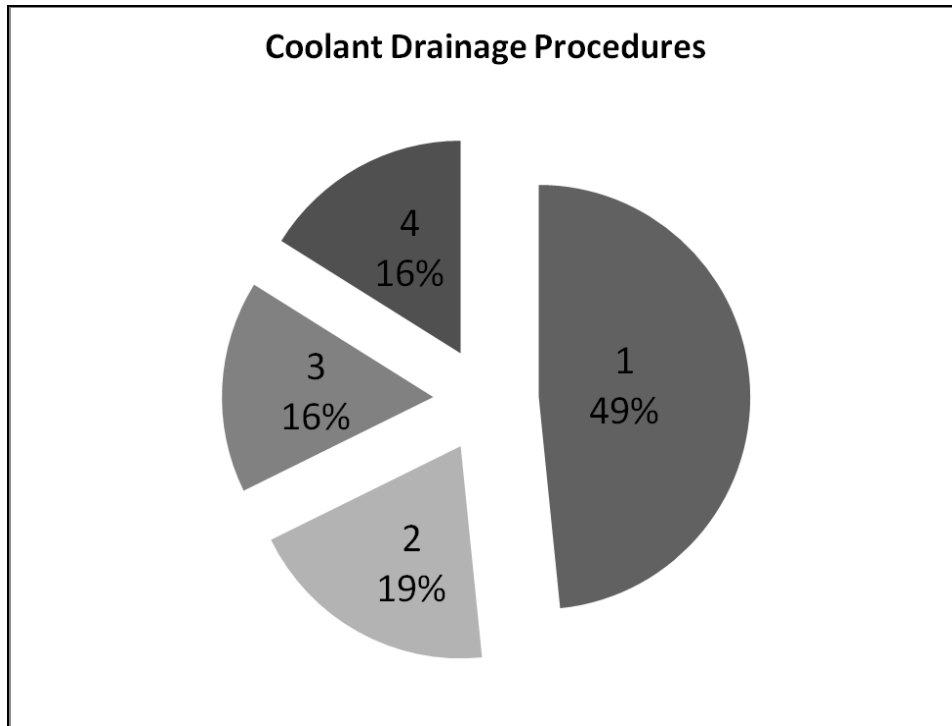


Figure 4.8: Coolant Drainage Procedure

Figure 4.8 illustrates the percentages of the four coolant drainage procedures followed by the companies. The pie chart reveals that approximately half of the companies surveyed are following the drainage procedure 1 i.e. drain nut is opened while the car is lifted up into a pan. This method is widely used in the automotive industry to drain coolant fluid in comparison to other drainage methods available. The vehicles are equipped with a drain nut for the drainage of the coolant oil and considered as one of the easier methods to drain out the fluid from ELVs. This method is widely practiced in India and only few of the companies are practicing this method in Canada.

The data in Table 4.4 validates that one-third out of the 49% companies following drainage procedure 1 are based in Canada. Whereas, the drainage procedure 3 and 4 are automatic methods and account for 16% each.

The table 4.4 shown below represents the categorical data obtained from the plant visits and survey including both the input and output parameters required to carry out the analysis. In addition, it also mentions about the usage of the coolant after the companies have drained it out. The concentration of ethylene glycol in the used coolant is minimal due to its decomposition in the vehicle and as a result, it does not account for much revenue for the company. However, during the visit to the recycling facilities in Canada it was observed that the used coolant fluid was stored in storage tanks outside the working facility and was made available to the public for no-charge.

Table 4.4: Coolant Categorical Data obtained from survey and facility visits

Location	Name of Company	Fluid	Fluid Drainage Procedure				Transferring of used coolant to the huge tanks/drums outside			Number of working bays			Drainage Time depending upon the procedure			Quantity drained out depending upon the procedure			No. of cars processed daily depending upon the procedure			Usage of the fluids					
			Drain nut is opened while the car is lifted up into a pan	Hose is opened/cut while the car is lifted up into a pan/drum	Suction by inserting a pipe into the radiator cap	Suction by piercing the radiator hose	None	Semi-automatic	Automatic	1 to 2	3 to 4	5 to 6	7 to 8	15 - 30 mins	11 - 25 mins	10 mins - 22 mins	8 mins - 20 mins	0 - 6 hr	0 - 8 hr	0 - 10 hr	0 - 15 hr	1 to 10	1 to 12	1 to 20	16 to 40	Reuse	Sell to a recycling facility
Chandigarh	Padam Motors	x	1				2					2										2				1	
Chandigarh	G.M. Motors	x	1				2					1										2				1	
Chandigarh	Joshi Tata	x	1				2				3											2		3		1	
Chandigarh	Bhagat Ford	x	1				2				1											2		2		1	
Chandigarh	Berkley Maruti	x	1		3		2				4											2		3		1	
Chandigarh	Harmony Honda	x	1				2				4											2		4		1	
Chandigarh	Charisma Hyundai	x	1				2				2											2		3		1	
Chandigarh	Audi Chandigarh	x	1	3			3				3											2		3		1	
Chandigarh	Globe Toyota	x	1				3				2											2		3		1	
Chandigarh	Joshi Mercedes	x	1				3				3											2		3		1	
Patiala	Hira Maruti	x	1				2				4											2		3		1	
Patiala, Chandigarh	Scarp dealers	x	1	2			1				1											1		1		1	
Chandigarh	Krishna BMW	x	1				2				2											2		3		1	
Kicheener	Loge's Auto Parts	x		2			3				1											1		3		1	
London	LKQ Slaw Auto Recyclers	x				4					2													4		1	
London	Andy's Auto Wreckers	x	1				2				1											2		2		1	
London	Corey's Auto Wreckers	x	1	3			2				4											2		3		1	
Mississauga	Cooksville Auto Recyclers	x	1				2				1											2		2		1	
Mississauga	Northqueen Auto Wreckers	x	1				2				2											2		3		1	
Courice	Dom's Auto Parts	x		2			4				3											2		2		1	
Oshawa	Oshawa Auto Parts	x		2			2				1											2		2		1	
Ajax	Ajax Auto Wreckers	x				4					4											2		4		1	
Aurora	Carcoori's Auto Recycling	x	1				2				4											2		2		1	
Aurora	Hillop Auto Wreckers	x				3					1											2		3		1	
Cookstown	Cookstown Auto Center	x	1				2				2											2		2		1	
Markham	Standard Auto Wreckers	x				4					4											2		4		1	
Oakville	Ontario Auto Salvage	x		3			3				1											2		3		1	
Hamilton	Bodyline Auto Wreckers	x				4					4											2		4		1	
Leamington	A & L Auto Recyclers	x				4					4											2		4		1	
Windsor	J & B Auto Recyclers	x		2			2				1											2		1		1	
Kicheener	Plaeshi Motors	x		2			2				1											2		2		1	

I. Drain nut is opened while the car is lifted up into a pan

The vehicle is raised using the lifts for the easy accessibility underneath the vehicle. Firstly, it was ensured that the engine was cool enough such that it would not cause any physical injury to the worker. Considering, that the engine was cool as the vehicle was placed in the yard for several days, the radiator drain plug was located underneath the car. In addition, the radiator cap was also checked before the drainage of coolant. The drainage pan was properly placed under the radiator's drain valve. The valve was unscrewed using the wrench and the coolant was allowed to drain out in the pan. The drainage process was performed until it stopped dripping. The coolant was drained out and transferred into another bucket. Again, the valve was closed and a water hose was taken and inserted into the nozzle of the radiator cap along with full flow of water. The drain plug was again instantly removed and the mixture of coolant and water was collected in the pan. This process was repeated a few times until clear water was observed draining out from the valve. Hence, the coolant was finally removed from the vehicle after a time consuming iterative process.



Figure 4.9: Coolant Drainage Method 1

However, the effect of choosing this method on the drainage time and the quantity of coolant drained out have been analyzed by performing statistical analysis on the data available.

II. Hose is opened/cut while the car is lifted up into a pan/long drum

While visiting the scrap dealers in India it was observed that the workers were no longer interested in draining out the coolant from the drain plug and to expedite the process the hose connecting the radiator fan and the engine was opened or cut using a knife. The pan/long drum was instantly positioned underneath the opened hose and the coolant fluid was drained out. However, spillages occurred when the worker cut the hose and caused environmental pollution.



Figure 4.10: Coolant Drainage Method

This method has been followed by 19% of the total survey responses received as seen in figure 4.8 and mostly in Canada with an exception of scrap dealers in India.

In-order to follow this method, any sharp object was used to cut/open the hose. The worker easily identified the connecting hose and drained out the fluid. It saved the extra time required by the worker to locate the drain plug, get appropriate tool to open the drain nut and then drain out the fluid. As a result, less time was required to follow this method in comparison to the previous method.

III. Suction by inserting a pipe into the radiator cap

One of the semi-automatic methods for the drainage of the coolant fluid from ELVs is through suction i.e. by inserting a pipe into the radiator cap. Furthermore, there are two methods i.e. manual and automatic suction method. In both the manual and automatic suction methods, the vehicle is not required to be lifted up. The suction equipment is placed closer to the vehicle and the used coolant fluid is drained out.

In a manual method, the worker creates suction by pressing the lever up and down repeatedly as seen in the left figure below. The temperature of the radiator cap is checked before its opened to prevent an injury to the worker. After the cap has been opened, the worker inserts the other end of

the hose into the radiator cap. Then, the lever is operated and while maintaining consistent suction pressure resulting in the drainage of the coolant fluid into the equipment. On the other hand, in an automatic suction method after the hose is inserted into the radiator cap. The suction machine as shown in the right figure below is turned on thus creating suction pressure inside the hose. The other loose end of the hose is inserted into the drum/bucket to collect the coolant fluid. The benefits of this method is that it saves time, minimizes environmental pollution, and multiple tasks can be performed by the worker.

The analyses of the survey responses have shown that 16% of the total companies are following this method for the drainage of the coolant fluid in both India and Canada as seen in figure 4.9.



Figure 4.11: Coolant Drainage Method 3

Berkeley Maruti in Chandigarh is presently using the coolant drainage machine seen in the figure 4.11 and similar suction machines have been witnessed at AUDI in Chandigarh, and few of the automotive recycling companies in Canada.

IV. Suction by piercing the radiator hose – automatic

One of the fully automatic methods found during the plant visits to Canada was by piercing the radiator hose and then using suction equipment to instantly drain out all the coolant fluid from the vehicle. This automatic method also accounts for 16% of the total survey responses as for the previous method seen in figure 4.8. It implies that in total 32% of the total responses prefer suction method for the drainage of the coolant fluid from the ELVs as observed in figure 4.8.

During this method, the vehicle is lifted to a certain height, allowing the worker to have access underneath the vehicle. The worker identifies the lowest point of the coolant connecting hose. A tool with a sharp tip is used to pierce into the connecting hose as seen in figure 4.12. The piercing tool is connected to an automatic suction pump that automatically drains out the coolant fluid into

the storage tanks located outside the facility. The suction pump is set aside for few extra minutes to ensure that all the coolant fluid has been drained out. In the meanwhile, the worker can perform other dismantling activities on the ELV while the fluid is being drained out.

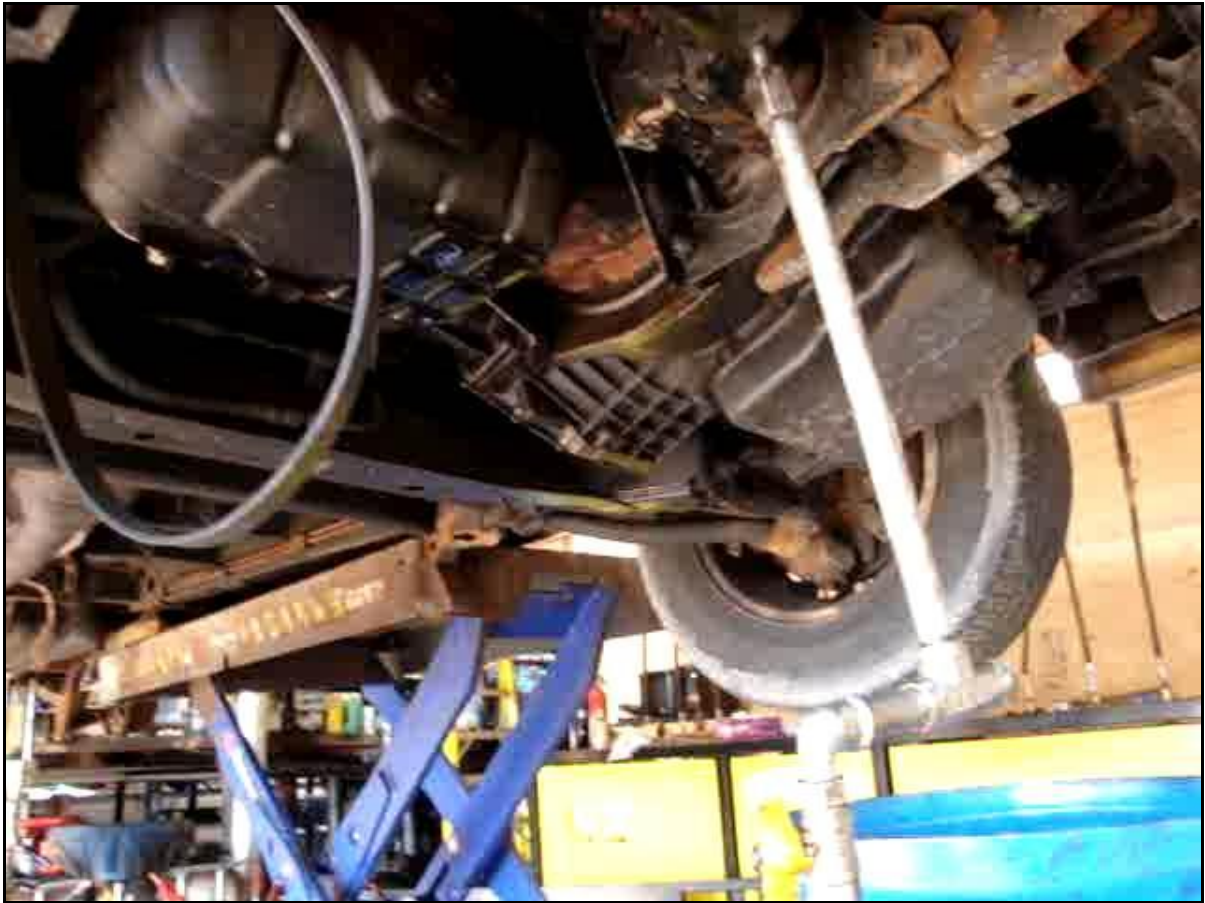


Figure 4.12: Coolant Drainage Method 4

The piercing tool used is clearly observable in the above figure. It is a time-efficient, environmentally friendly and allows multi-tasking operations to be performed by the worker.

4.6 Transfer of used fluids from drums to storage tanks outside the facility

The used fluids collected in the drums/pans further needs to be transferred to the storage tanks located outside the facility. It has been observed that thousands of litres of fluids are being collected weekly at the automotive facilities and proper storage tanks are required for the safety of the environment and to prevent any fire hazards. In-order to prevent any spillages during the transferring of oil proper techniques need to be implemented.

This is among one of the input factors considered for the research study and its impact on the output factors have been discussed to develop a proposed solution and accomplish the objectives.

The outcome of the plant visits was that following methods were found:

- I. Method used by scrap dealers
- II. Manual
- III. Semi-Automatic
- IV. Fully Automatic

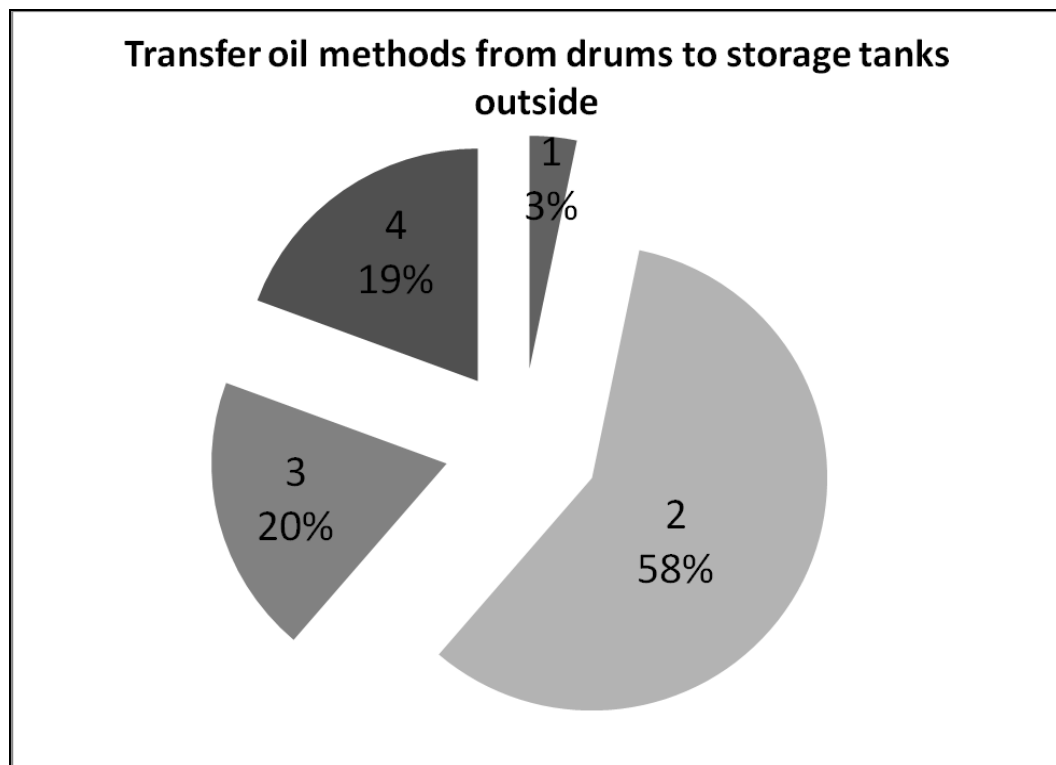


Figure 4.13: Transfer oil method from drums to storage tanks outside – engine and gear oil

The figure 4.13 illustrates the different percentages of transfer oil methods obtained from the survey responses for automotive fluids from ELVs.

I. Method used by scrap dealers

The scrap dealers in India followed no specific method for the transfer of used oil. Only a little amount was drained out and collected in small containers such as bottles or buckets, which can be used as furnace oil or for greasing purposes in the vehicles. It accounts for only 3% of the total survey responses received as seen in figure 4.13.

II. Manual method

During the plant visits in India, it was observed that manual method is more commonly used. Whereas, in Canada manual methods is preferred by the small-scale recyclers compared to large-scale recyclers who prefer either semi-automatic or fully automatic method. However, this method

resulted in spillages on the soil, environmental pollution, time-consuming process for the worker and not economical for the company as well. Out of the total survey responses, 58% depict the usage of this method as observed in figure 4.13.



The worker has to manually transfer the used oil from the 30 litres drum into the storage tanks located outside the working area of the facility. In India, it was observed that cups were used to transfer oil from the drums and later on, the long drum was tilted to empty out into the storage tank. During this process, many spillages occurred on the floor and contaminated the soil and the environment as seen in the figure. It also posed threat to the health of the worker as their hands used to be all filled with the oil.



Figure 4.14: Transfer oil method II

The figure 4.14 illustrates the location of the huge storage tanks outside the facility as observed in Canada. A round inlet can be seen in the figure where the worker tilts the drum into it and completely empties out the used oil into the storage tank. The recycling companies such as Safety Kleen Inc. visit the facilities on a bi-weekly or monthly basis to collect the used fluids and recycle it.

Even though this method is widely used but an innovative method needs to be implemented at the facilities currently, practicing this method to save the environment and health of the workers involved.

III. Semi – automatic method

Semi-automatic method is a mix of the manual and fully automatic methods. According to the response survey, 20% of the companies are practicing this method in both India and Canada as seen in figure 4.13.

During this method, the oil stored in the container or the drum is transferred through a hose directly to the storage tanks outside. A suction pump is fitted and hose is attached to one end of the nozzle located on the drum and oil is transferred out directly. In India, companies such as Honda, Audi,

Toyota, Mercedes etc. are currently practicing this method. However, in Canada only few of the companies are practicing this method according to the survey response tabulated in Table 4.2.

The semi-automatic method eliminates the transportation of the drum to the storage tanks located outside thus minimizing the environmental hazard and improving the health of the workers.



Figure 4.15: Transfer oil method: semi-automatic

The figure 4.15 clearly illustrates the ‘waste oil sump’ located on the wall. The hose is attached to the long drum in which the used oil is collected. The storage tank is located outside the facility and by just turning, the nozzle to ‘on’ position the used oil is transferred in couple of minutes and empties out the drum. This drum is now available immediately for the collection of used oils from the other vehicles. As a result, ample amount of time was saved and more vehicles were processed in the same time.

Hence, this method is certainly a good alternative in comparison to the manual method chosen by most of the facilities.

IV. Fully-automatic method

This method involves the direct transfer of used oil from the vehicle to the storage tanks located outside. The worker does not store the used oil in drums or containers. A suction hose is attached to the oil drainage equipment and used oil is transferred out.

This method was observed only in Canadian recycling facilities and accounts for 19% of the total survey responses as seen in figure 4.13.



Figure 4.16: Transfer oil method: Fully Automatic

The figure 4.16 depicts the different oil storage containers located outside the facility. A hose is attached at one of the inlets to the storage tanks and used oil is directly stored into them. The recycling companies such as Safety Kleen bring their even huge tanks, connect their hoses to these tanks, and automatically transfer out the used oil in a few minutes.

Hence, the fully automatic transfer of oil method eliminates the environmental hazards, safety of the workers and makes the process very time-efficient.

After analyzing the responses of the survey based on two input factors i.e. fluid drainage procedure and transfer of oil method from drums to the storage tanks outside it can be analyzed visually that a system to fulfill the objectives of the research study should consider the input parameters. The input parameters discussed earlier provide in-depth knowledge of the outcomes of the various methods currently in practice. These input parameters have been statistically analyzed along with output parameters to develop a proposed solution for the research problem. In addition, the internal reliability of items for the engine oil, gear oil, coolant oil and petrol/diesel have been assessed by using Cronbach's Alpha co-efficient. Cronbach's Alpha coefficient measures the extent to which a set of variables are consistent in what they are intended to measure.

4.7 Internal Reliability Analysis

The questionnaire prepared for the purpose of data collection need to be validated for internal reliability of the questions asked from the companies. The internal reliability analysis of the questions has been assessed by using Cronbach's Alpha co-efficient in SPSS. The co-efficient

measures the reliability and validity of the input and output parameters considered in the questionnaire. Cronbach's Alpha values have been calculated for the automotive fluids from ELVs and are presented in the tables below.

Table 4.5: Cronbach's Alpha Calculated Values

Oil	Cronbach's Alpha	N of Items
Engine Oil	.819	6
Gear Oil	.810	6
Coolant	.828	6
Petrol/Diesel	.794	5

It can be seen from table 4.5 that the Cronbach's Alpha co-efficient values obtained for four different fluids are > 0.8 , which specifies a high level of internal consistency for the factors considered. This also indicates high reliability of data collected through survey responses and by visiting the facilities. Generally, as a rule of thumb Cronbach's Alpha coefficient ≥ 0.70 is considered as an acceptable reliability coefficient. (Nunnaly, 1978)

In the case of petrol/diesel, five factors were considered since transferring of petrol/diesel from drums method was not observed in India. Since the data was missing for Indian companies, the input parameter was eliminated while performing the analysis. It resulted in a value close to 0.8, which is still acceptable for the research study and suggests higher degree of inter correlation among the test items.

Therefore, the questionnaire prepared is a reliable source to collect data from the companies, which has been proved by the Cronbach's Alpha co-efficient values obtained.

4.8 Association between Input and Output Performance Parameters

In this part of analysis, the impact of the drainage procedure/method in achieving performance improvements in the industry has been evaluated. Partial Correlation analysis has been performed to identify the association between input and output factors. The correlation coefficient values (r values) have been calculated and further applied using Multinomial Logistic Regression analysis.

4.8.1 Partial Correlation Analysis

The partial correlation analysis computes correlation coefficients that describe the linear relationship between two variables while controlling for the effects of one or more additional variables. The variables chosen for the analysis are required to be scale variables. [SPSS]

Scale variable can be defined as a variable that can be treated as a scale when its values represent ordered categories with a meaningful metric, so that distance comparisons between values are appropriate. [SPSS]

For the purposes of the research study, fluid drainage procedure, measured as an independent variable, is a predictor for drainage time. However, drainage time of the vehicle might be influenced by other factors as well such as transfer of oil method from drums to the storage tanks outside the facility. A partial correlation analysis is carried out to clarify the relationship between drainage procedure and the drainage time, controlling for transfer of oil method. Since, one factor has been kept as constant out of a correlation; the partial correlation coefficient performed is called a ‘first order partial correlation’.

The partial correlation analysis has been performed for engine oil, gear oil and coolant. Various partial correlation coefficients have been calculated considering different factors for each of the oils mentioned above. The results obtained after performing partial correlation analysis have been discussed below.

4.8.1.1 Drainage Procedure and Drainage Time

Firstly, the correlation coefficient has been calculated for the two factors i.e. drainage process (DP) and drainage time (DT) for engine oil, gear oil and coolant to determine the relationship among them.

Table 4.6: Correlation Coefficient between DP and DT for engine oil

Correlations			DP	DT
Control Variables				
TO	DP	Correlation	1.000	.613
		Significance (2-tailed)	.	.000
		df	0	28
	DT	Correlation	.613	1.000
		Significance (2-tailed)	.000	.
		df	28	0

However, it can be seen in Table 4.6, that when transfer oil method was controlled, the correlation coefficient between the drainage procedure and drainage time of engine oil is 0.613. The correlation coefficient is significant ($p = 0.000$) at 5 percent level, which highlights significant association between drainage procedure and drainage time. The values of the drainage procedure and drainage time of engine oil are affected by each other’s when transfer oil method is controlled variable.

Similarly, partial correlation coefficient has been calculated considering similar parameters for gear oil. The results obtained using SPSS are as follows:

Table 4.7: Correlation Coefficient between DP and DT for gear oil

Correlations			DP	DT
Control Variables			DP	DT
TO	DP	Correlation	1.000	.439
		Significance (2-tailed)	.	.015
		df	0	28
DT	DT	Correlation	.439	1.000
		Significance (2-tailed)	.015	.
		df	28	0

The analysis of drainage procedure and drainage time when transfer oil method is controlled reveals that the factors of gear oil are less correlated ($r = 0.439$) than engine oil, $r = 0.613$ as seen in table 4.6. There still exists a positive significant ($p < 0.05$) correlation among the drainage procedure and drainage time.

Table 4.8: Correlation Coefficient between DP and DT for coolant

Correlations			DP	DT
Control Variables			DP	DT
TO	DP	Correlation	1.000	.393
		Significance (2-tailed)	.	.032
		df	0	28
DT	DT	Correlation	.393	1.000
		Significance (2-tailed)	.032	.
		df	28	0

SPSS results as presented in the table 4.8 provide that drainage procedure and drainage time for the coolant fluid are positively correlated with a value of 0.393. The correlation for the coolant fluid has more variations as compared to the correlation coefficient values obtained for engine oil and gear oil previously.

The table 4.9 shown below illustrates the summary of the correlation coefficient values for the drainage procedure and drainage time when transfer of oil method is controlled for the three oils considered. The results illustrate a positive association that if the drainage procedure chosen were manual then the drainage time would also increase. Moreover, the results obtained statistically

match the practical observations of the affect of choosing the drainage procedure on drainage time during the visits to the facilities and thus verifying the results obtained.

Table 4.9: Summary of Correlation Coefficeints for DP and DT

Controlled Variable	Type of Oil	Drainage Procedure	Drainage Time	Significance (p-value)
Transfer Oil Method	Engine Oil	1.000	0.613	0.000
	Gear Oil	1.000	0.439	0.015
	Coolant	1.000	0.393	0.032

4.8.1.2 Drainage Procedure and Quantity drained out

Secondly, the correlation has been determined between the two factors i.e. drainage process (DP) and quantity drained out (QT) while considering transfer of oil method (TO) factor as controlled for engine oil, gear oil and coolant.

Table 4.10: Correlation Coefficient between DP and QT for engine oil

Correlations			DP	QT
Control Variables				
TO	DP	Correlation	1.000	.829
		Significance (2-tailed)	.	.000
		df	0	28
QT	DP	Correlation	.829	1.000
		Significance (2-tailed)	.000	.
		df	28	0

From the results seen in Table 4.10, there is a very strong positive correlation between drainage procedure and the quantity of engine oil drained out from the vehicle with a coefficient value of 0.829, when transfer oil method was controlled. This implies that if the companies choose a different drainage procedure for engine oil, then the quantity of engine oil drained out will be effected by 83% as seen in the above table.

Error! Not a valid bookmark self-reference. depicts the association between drainage procedure and quantity of gear oil drained out while transfer of oil method is controlled. It can be analyzed that if the effect of transfer oil method is removed from the drainage procedure and quantity of gear

oil drained out then the correlation coefficient is found to be 0.372. The correlation coefficient calculated is significant ($p < 0.05$), which highlights significant association between drainage procedure and quantity of gear oil drained out.

Table 4.11: Correlation coefficient between DP and QT out for gear oil

Correlations			DP	QT
Control Variables			DP	QT
TO	DP	Correlation	1.000	.372
		Significance (2-tailed)	.	.043
		df	0	28
QT	QT	Correlation	.372	1.000
		Significance (2-tailed)	.043	.
		df	28	0

The statistical correlation results in Table 4.12 reveal that there is a strong correlation between drainage procedure and quantity of coolant fluid drained out from the vehicle when transfer of oil method was controlled. This has been inferred in support of the correlation value of 0.530 as seen in the above table when tested for two-tailed significance at 95 percent confidence interval.

Table 4.12: Correlation coefficient between DP and QT for coolant

Correlations			DP	QT
Control Variables			DP	QT
TO	DP	Correlation	1.000	.530
		Significance (2-tailed)	.	.003
		df	0	28
QT	QT	Correlation	.530	1.000
		Significance (2-tailed)	.003	.
		df	28	0

4.8.1.3 Drainage Procedure and No. of cars processed daily

In-order to have an efficient drainage system in the automotive recycling industry, it is very important to consider the output parameter i.e. number of cars processed daily at a facility. As a result, partial correlation analysis has been performed between drainage procedure (DP) and number of cars processed (CP) keeping number of working bays (WB) as a controlled factor.

Table 4.13: Correlation coefficient between DP and CP for engine oil

Correlations			DP	CP
WB	DP	Correlation	1.000	.630
		Significance (2-tailed)	.	.000
		df	0	28
	CP	Correlation	.630	1.000
		Significance (2-tailed)	.000	.
		df	28	0

From the results obtained in SPSS, a correlation coefficient value of 0.630 with a significance value of 0.000 defines a strong connection between drainage procedure and the number of cars processed for engine oil, when number of working bays was controlled are displayed in Table 4.13. As a result, number of cars processed is linearly correlated with the drainage procedure chosen by the company.

Table 4.14: Correlation coefficient between DP and CP for gear oil

Correlations			DP	CP
WB	DP	Correlation	1.000	.328
		Significance (2-tailed)	.	.077
		df	0	28
	CP	Correlation	.328	1.000
		Significance (2-tailed)	.077	.
		df	28	0

The results in Table 4.14 describe that, there exists a linear association between the drainage procedure and number of cars processed since the correlation coefficient has a value of 0.328 but the results obtained are less significant ($p > 0.05$). This means that if a different drainage procedure is chosen for the gear oil then it cannot be concluded that it would affect the number of cars processed. Hence, other factors might be contributing more towards the number of cars processed than drainage procedure in this scenario.

Table 4.15: Correlation coefficient between DP and CP for coolant

Correlations			DP	CP
Control Variables				
WB	DP	Correlation	1.000	.348
		Significance (2-tailed)	.	.060
		df	0	28
	CP	Correlation	.348	1.000
		Significance (2-tailed)	.060	.
		df	28	0

Partial correlation analysis reveals that drainage procedure for the coolant fluid is linearly correlated with the number of cars processed when the number of working bays is controlled. This has been validated by obtaining a positive value of 0.348 for the correlation coefficient as seen in Table 4.15 but will less significance since the value of $p > 0.05$. Therefore, regression analysis has to be performed to determine the contribution of other factors on the number of cars processed daily for coolant fluid.

4.8.2 Pearson Correlation analysis

The present study considers number of working bays as the key input parameter for the implementation of an efficient method to process maximum number of cars in a day. The contribution of this parameter in achieving performance improvements in the Indian automotive industry has been discussed. As a result, Pearson's correlation coefficient values (r-values) between number of cars processed (CP) and number of working bays (WB) has been calculated.

Table 4.16: Correlation coefficient between WB and CP for engine oil

		WB	CP
WB	Pearson Correlation	1	.571 [*]
	Sig. (2-tailed)		.001
	N	31	31
CP	Pearson Correlation	.439 [*]	1
	Sig. (2-tailed)	.014	
	N	31	31

The results in Table 4.16 show that number of cars processed daily for engine oil is strongly associated with the number of working bays in a facility as the correlation coefficient has a value of 0.571 for two-tailed significance test at 95% confidence interval. The statistical values obtained in

SPSS have justified the practically observed relationship between the cars processed for engine oil drainage and number of working bays.

Table 4.17: Correlation coefficient between WB and CP for gear oil

Correlations			
		WB	CP
WB	Pearson Correlation	1	.467*
	Sig. (2-tailed)		.008
	N	31	31
CP	Pearson Correlation	.439*	1
	Sig. (2-tailed)	.014	
	N	31	31

Similarly, it has been found that at a significance level of 0.05, number of working bays influences the number of cars processed for the gear oil drainage in a facility. The strong linear correlation has been established with a correlation coefficient of 0.467 as seen in Table 4.17. The result obtained for the gear oil is comparable to the coefficient value obtained for engine oil since, the drainage process of gear oil and engine oil were performed simultaneously at several facilities visited. However, slight variation is because few of the Indian service centers do not drain out both the oils at the same time, thus consuming more time and processing less number of cars daily.

Table 4.18: Correlation coefficient between WB and CP for coolant

Correlations			
		WB	CP
WB	Pearson Correlation	1	.596
	Sig. (2-tailed)		.000
	N	31	31
CP	Pearson Correlation	.439*	1
	Sig. (2-tailed)	.014	
	N	31	31

Furthermore, the correlation coefficient between the number of working bays and the cars processed for coolant drainage has been computed as 0.596 as observed in Table 4.18. It defines a strong positive linear correlation between the two factors considered. In addition, the significance of the correlation between the factors ($p = 0.000$) verifies that there exists a significant relation for 95% confidence interval.

In conclusion, it can be stated that if there were an increase in the number of working bays at a facility, larger area would be available to process the vehicles for drainage thus, resulting in a linear increase in the number of cars processed at that facility. The above relationship has been statistically proved by performing Pearson Correlation analysis for the oils as discussed earlier.

4.8.3 Multinomial Logistic Regression Analysis

Multinomial logistic regression analysis is used to predict categorical placement in or the probability of category membership on a dependent variable based on multiple independent variables.

This regression analysis has been chosen for the research study, as the dependent variables has four categories and multinomial regression analysis is the only regression analysis tool that is not restricted to two categories.

4.8.3.1 Engine Oil

For a closer examination of relationship between engine oil drainage procedure chosen towards the number of cars processed daily and its determinants, multinomial regression has been used taking cars processed (CP) as dependent variable and drainage procedure (DP) , transfer of oil method (TO) and number of working bays (WB) as independent variables. The general purpose of the regression is to learn more about the relationship between several predictor variables and a criterion variable.

The results obtained by performing multinomial logistic regression analysis in SPSS can be seen in Table 4.19

The Table 4.19a illustrates the frequency distribution of the four categories for the dependent and independent variables obtained from the respondents of the survey and plant visits.

From Table 4.19c the beta values are obtained from the column 'AIC of Reduced Model' for the regression model. The regression equation for the model is as follows:

$$Y = 59.885 + (75.282)\text{Drainage Process} + (53.936)\text{Transfer Oil Method} + (65.676)\text{Working Bays}$$

and R-square value, for this fitting is 0.896 as seen in Table 4.19b.

The r-squared value of 0.896 suggests that the model fits increasingly well considering the parameters chosen. Therefore, the β values of drainage process and number of working bays contribute maximum to improve the numbers of cars processed which indicates that a unit change in these predictor variables has a large effect on criterion variable.

Table 4.19: Regression Model for CP - Engine Oil

Table 4.19a: Case Processing Summary

		N	Marginal Percentage
CP	1	4	12.9%
	2	10	32.3%
	3	9	29.0%
	4	8	25.8%
DP	1	7	22.6%
	2	14	45.2%
	3	4	12.9%
	4	6	19.4%
TO	2	18	58.1%
	3	7	22.6%
	4	6	19.4%
WB	1	12	38.7%
	2	9	29.0%
	3	4	12.9%
	4	6	19.4%
Valid		31	100.0%
Missing		0	
Total		31	
Subpopulation		20 ^a	

Table 4.19b: Pseudo R-Square

Cox and Snell	.896
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Table 4.19c: Likelihood Ratio Tests

Effect	Model Fitting Criteria		
	AIC of Reduced Model	df	Sig.
Intercept	59.885	0	.
DrainageProcess	75.282	9	.000
TransferOilMethod	53.936	6	.418
WorkingBays	65.676	9	.005

Analysis of multivariate statistics for quantity of engine oil drained out (QT) has been considered as a dependent variable while the drainage procedure (DP) and transfer of oil method (TO) are considered as independent variables. The results obtained by performing multinomial logistic regression analysis in SPSS are as follows:

Table 4.20: Regression Model for QT - Engine Oil

Table 4.20a: Case Processing Summary

		N	Marginal Percentage
QT	1	7	22.6%
	2	9	29.0%
	3	7	22.6%
	4	8	25.8%
DP	1	7	22.6%
	2	14	45.2%
	3	4	12.9%
	4	6	19.4%
TO	2	18	58.1%
	3	7	22.6%
	4	6	19.4%
Valid		31	100.0%
Missing		0	
Total		31	
Subpopulation		8 ^a	

Table 4.20b: Pseudo R-Square

Cox and Snell	.839
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Table 4.20c: Likelihood Ratio Tests

Effect	Model Fitting Criteria		
	AIC of Reduced Model	df	Sig.
Intercept	46.510	0	.
DrainageProcess	55.880	9	.001
TransferOilMethod	48.494	6	.030

The Table 4.20a illustrates the frequency distribution for the quantity of engine oil drained out, drainage procedure and transfer of oil method chosen by the companies. The results displayed are in percentages as well for better understanding.

For multinomial regression between the criterion and predictor variables performed, the beta values obtained for the drainage process, and transfer oil method are 55.880 and 48.494 respectively as obtained from Table 4.20c. The resulting regression equation for this model is:

$$Y = 46.510 + (55.880)DrainageProcess + (48.494)TransferOilMethod$$

and R-square value of 0.839 as observed in Table 4.20b.

The two predictor factors considered have approximately equal impact on the quantity of engine oil drained out from the vehicle and has been statistically proved above. Therefore, to drain out maximum engine oil from a vehicle, the company should apply the best-chosen drainage method along with the best transfer oil method.

Multinomial logistic regression has also been carried for examining the relationship between the drainage time (DT) as criterion variable and a set of independent variables. The independent variables taken into account are drainage procedure (DP), transfer of oil method (TO), and quantity of oil drained out (QT).

The results of multinomial logistic regression analysis for drainage time as criterion variable are summarized in Table 4.21 below.

The Table 4.21a illustrates the frequency distribution as percentages for the drainage time, drainage procedure, transfer of oil method, and quantity of engine oil drained out from ELVs.

Table 4.21c reveals the intercept and beta value required for the development of multinomial logistic regression equation. The concluding regression equation for the drainage time is:

$$Y = 55.386 + (64.843)DrainageProcess + (43.386)TransferOilMethod + (38.433)QuantityofOilDrained$$

and R-square value for the model is 0.919 as seen in Table 4.21b.

The significance column in Table 4.21c depicts that the criterion variable, drainage time has a significant ($p = 0.001$) relation with the predictor variable in comparison to the other predictor variables i.e. transfer of oil method and quantity of engine oil drained out since the value of p is approximately equal to 1. As a rule of thumb in statistics the value of $p = 1.00$ defines a non-significant relationship among the factors considered. However, the β values obtained for transfer oil method and quantity of engine oil drained out would always have a minor contribution towards the prediction of drainage time from the vehicle.

Table 4.21: Regression Model for DT - Engine Oil

Table 4.21a: Case Processing Summary

		N	Marginal Percentage
DT	1	13	41.9%
	2	7	22.6%
	3	4	12.9%
	4	7	22.6%
DP	1	7	22.6%
	2	14	45.2%
	3	4	12.9%
	4	6	19.4%
TO	2	18	58.1%
	3	7	22.6%
	4	6	19.4%
QT	1	7	22.6%
	2	9	29.0%
	3	7	22.6%
	4	8	25.8%
Valid		31	100.0%
Missing		0	
Total		31	
Subpopulation		14 ^a	

Table 4.21b: Pseudo R-Square

Cox and Snell	.919
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Table 4.21c: Likelihood Ratio Tests

Effect	Model Fitting Criteria		
	AIC of Reduced Model	df	Sig.
Intercept	55.386	0	.
DrainageProcess	64.843	9	.001
TransferOilMethod	43.386	6	1.000
Quantity	38.433	9	.999

4.8.3.2 Gear Oil

For a closer examination of relationship between gear oil drainage procedure chosen towards the number of cars processed daily and its determinants, multinomial regression has been used taking cars processed (CP) as dependent variable and drainage procedure (DP), transfer of oil method (TO) and number of working bays (WB) as independent variables.

The results obtained by performing multinomial logistic regression analysis in SPSS are shown in Table 4.22.

Table 4.22: Regression Model for CP - Gear Oil

Table 4.22a: Case Processing Summary

		N	Marginal Percentage
CP	1	4	12.9%
	2	10	32.3%
	3	9	29.0%
	4	8	25.8%
DP	1	8	25.8%
	2	8	25.8%
	3	5	16.1%
	4	10	32.3%
TO	2	18	58.1%
	3	7	22.6%
	4	6	19.4%
WB	1	12	38.7%
	2	9	29.0%
	3	4	12.9%
	4	6	19.4%
Valid		31	100.0%
Missing		0	
Total		31	
Subpopulation		21 ^a	

Table 4.22b: Pseudo R-Square

Cox and Snell	.850
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Table 4.22c: Likelihood Ratio Tests

Effect	Model Fitting Criteria	df	Sig.
	AIC of Reduced Model		
Intercept	69.855	0	.
DrainageProcess	73.896	9	.009
TransferOilMethod	80.781	6	.001
WorkingBays	78.389	9	.002

The Table 4.22a illustrates the frequency distribution of the four categories for the dependent and independent variables obtained from the respondents of the survey and plant visits.

From Table 4.22c the beta values for regression equation are obtained and the equation developed after substituting the values is as follows:

$$Y = 69.855 + (73.896)\text{Drainage Process} + (80.781)\text{Transfer Oil Method} + (78.389)\text{Working Bays}$$

and R-square value, for this fitting is 0.850 as seen in Table 4.22b.

The value of 0.850 illustrates the goodness-of-fit for the model. The significance column in Table 4.22c reveals that all the predictor variables have a significant ($p < 0.05$) impact on the criterion variable i.e. number of cars processed at a facility for the gear oil drainage.

Furthermore, Multinomial Regression analysis has been performed to determine the relationship between quantity of gear oil drained out (QT) and the independent variables i.e. the drainage procedure (DP) and transfer of oil method (TO).

The results obtained by performing multinomial logistic regression analysis in SPSS have been shown in Table 4.23 below.

The Table 4.23a illustrates the frequency distribution for the quantity of engine oil drained out, drainage procedure and transfer of oil method chosen by the companies. The results displayed are in percentages as well for better understanding.

The regression equation for this model has been developed by considering the statistical values obtained as shown in Table 4.23c:

$$Y = 55.079 + (54.227)\text{DrainageProcess} + (61.773)\text{TransferOilMethod}$$

And R-square value of 0.776 as seen in Table 4.23b.

The drainage process and transfer of oil method parameters considered have approximately equal impact on the quantity of gear oil drained out from the vehicle and has been statistically proved by observing the significance values in Table 4.23c. The drainage process and transfer oil method have a relatively strong significant ($p < 0.05$) effect on the quantity of gear oil drained out from the vehicles.

Table 4.23: Regression Model for QT - Gear Oil

Table 4.23a: Case Processing Summary

		N	Marginal Percentage
QT	1	7	22.6%
	2	9	29.0%
	3	7	22.6%
	4	8	25.8%
DP	1	8	25.8%
	2	8	25.8%
	3	5	16.1%
	4	10	32.3%
TO	2	18	58.1%
	3	7	22.6%
	4	6	19.4%
Valid		31	100.0%
Missing		0	
Total		31	
Subpopulation		10 ^a	

Table 4.23b: Pseudo R-Square

Cox and Snell	.776
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Table 4.23c: Likelihood Ratio Tests

Effect	Model Fitting Criteria		
	AIC of Reduced Model	df	Sig.
Intercept	55.079	0	.
DrainageProcess	54.227	9	.046
TransferOilMethod	61.773	6	.005

Lastly, the regression analysis has also been carried out for determining the relationship between the drainage time (DT) and drainage procedure (DP), transfer of oil method (TO), and quantity of gear oil drained out (QT) from the vehicles. The model developed determines the contribution of each parameter on the drainage time along with its relevant significance levels.

The results obtained by performing multinomial logistic regression analysis in SPSS are illustrated in Table 4.24.

Table 4.24: Regression Model for DT - Gear Oil

Table 4.24a: Case Processing Summary

		N	Marginal Percentage
DT	1	9	29.0%
	2	9	29.0%
	3	6	19.4%
	4	7	22.6%
DP	1	8	25.8%
	2	8	25.8%
	3	5	16.1%
	4	10	32.3%
TO	2	18	58.1%
	3	7	22.6%
	4	6	19.4%
QT	1	7	22.6%
	2	9	29.0%
	3	7	22.6%
	4	8	25.8%
Valid		31	100.0%
Missing		0	
Total		31	
Subpopulation		17 ^a	

Table 4.24b: Pseudo R-Square

Cox and Snell	.896
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Table 4.24c: Likelihood Ratio Tests

Effect	Model Fitting Criteria		
	AIC of Reduced Model	df	Sig.
Intercept	60.218	0	.
DrainageProcess	63.801	9	.010
TransferOilMethod	52.716	6	.610
Quantity	61.876	9	.020

The Table 4.24a illustrates the frequency distribution as percentages for the drainage time, drainage procedure, transfer of oil method, and quantity of oil drained out from ELVs.

Table 4.24c reveals the multinomial logistic regression equation for the drainage time, which is:

$$Y = 60.218 + (63.801)DrainageProcess + (52.716)TransferOilMethod + (61.876)QuantityofOilDrained$$

and R-square value for the model is 0.896 as seen in Table 4.24b. The value of 0.896 represents a stable and highly fit model since this value is close to 1.

The predictor variables, drainage process and quantity of gear oil drained out have a significant ($p < 0.05$) influence on the criterion variable i.e. drainage time. However, the β value obtained for transfer oil method would have a small contribution towards the drainage time of the vehicle.

4.8.3.3 Coolant

For a closer examination of relationship between coolant drainage procedure chosen towards the number of cars processed daily and its determinants, multinomial regression has been used taking cars processed (CP) as dependent variable and drainage procedure (DP), transfer of oil method (TO) and number of working bays (WB) as independent variables. The general purpose of the regression is to learn more about the relationship between several predictor variables and a criterion variable.

Table 4.25 illustrates the different statistical results obtained by performing multinomial logistic regression analysis in SPSS.

The Table 4.25a illustrates the frequency distribution of the four categories for the dependent and independent variables obtained from the respondents of the survey and plant visits. As a result, it helps to determine the contribution of each company as percentage value towards the dependent variable.

Table 4.25: Regression Model for CP - Coolant

Table 4.25a: Case Processing Summary

		N	Marginal Percentage
CP	1	4	12.9%
	2	10	32.3%
	3	9	29.0%
	4	8	25.8%
DP	1	16	51.6%
	2	6	19.4%
	3	5	16.1%
	4	4	12.9%
TO	1	1	3.2%
	2	17	54.8%
	3	7	22.6%
	4	6	19.4%
WB	1	12	38.7%
	2	9	29.0%
	3	4	12.9%
	4	6	19.4%
Valid		31	100.0%
Missing		0	
Total		31	
Subpopulation		19 ^a	

Table 4.25b: Pseudo R-Square

Cox and Snell	.846
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Table 4.25c: Likelihood Ratio Tests

Effect	Model Fitting Criteria		
	AIC of Reduced Model	df	Sig.
Intercept	73.628	0	.
DrainageProcess	74.428	9	.027
TransferOilMethod	79.441	9	.005
WorkingBays	77.585	9	.009

From Table 4.25c the regression equation obtained is as follows:

$$Y = 73.628 + (74.428)\text{Drainage Process} + (79.441)\text{Transfer Oil Method} + (77.585)\text{Working Bays}$$

and R-square value, for this fitting is 0.846 as seen in Table 4.25b.

The value of 0.846 suggests that the model fits increasingly well considering the parameters chosen. Therefore, the β values for the predictor variables have a significant ($p < 0.05$) effect on the numbers of cars processed which indicates that a unit change in these predictor variables will have a large effect on criterion variable.

Analysis of multivariate statistics for quantity of coolant fluid drained out (QT) has been considered as a dependent variable while the drainage procedure (DP) and transfer of oil method (TO) are considered as independent variables.

The results obtained by performing multinomial logistic regression analysis in SPSS are seen in Table 4.26.

Table 4.26: Regression Model for QT - Coolant

Table 4.26a: Case Processing Summary

		N	Marginal Percentage
QT	1	4	12.9%
	2	16	51.6%
	3	5	16.1%
	4	6	19.4%
DP	1	16	51.6%
	2	6	19.4%
	3	5	16.1%
	4	4	12.9%
TO	1	1	3.2%
	2	17	54.8%
	3	7	22.6%
	4	6	19.4%
Valid		31	100.0%
Missing		0	
Total		31	
Subpopulation		10 ^a	

Table 4.26b: Pseudo R-Square

Cox and Snell	.762
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Table 4.26c: Likelihood Ratio Tests

Effect	Model Fitting Criteria		
	AIC of Reduced Model	df	Sig.
Intercept	56.495	0	.
DrainageProcess	53.546	9	.009
TransferOilMethod	59.496	9	.013

The Table 4.26a illustrates the frequency distribution for the quantity of coolant fluid drained out, drainage procedure and transfer of oil method chosen by the companies.

For multinomial regression between the criterion and predictor variables performed, the beta values obtained statistically as seen in Table 4.26c for the drainage process, and transfer oil method are 53.546, and 59.496 respectively. The resulting regression equation is:

$$Y = 56.495 + (53.546)DrainageProcess + (59.496)TransferOilMethod$$

and R-square value of 0.762 as observed in Table 4.26b.

The two-predictor factors considered have approximately equal impact on the quantity of coolant fluid drained out from the vehicle as statistically proved above. In addition, the significant column in Table 4.26c illustrates that both the drainage process and transfer of oil method have a significant value i.e. $p < 0.05$ for the model considered. Therefore, to drain out maximum coolant fluid from a vehicle, the company should apply the best chosen drainage method along with the best transfer oil method.

Lastly, the logistic regression analysis has been performed for the drainage time (DT) variable and a set of independent variables. The independent variables considered are drainage procedure (DP), transfer of oil method (TO) and quantity of coolant fluid drained out (QT).

The statistical results obtained in SPPSS for the multinomial logistic regression analysis have been illustrated below in Table 4.27.

Table 4.27: Regression Model for DT - Coolant

Table 4.27a: Case Processing Summary

		N	Marginal Percentage
DT	1	7	22.6%
	2	13	41.9%
	3	6	19.4%
	4	5	16.1%
DP	1	16	51.6%
	2	6	19.4%
	3	5	16.1%
	4	4	12.9%
TO	1	1	3.2%
	2	17	54.8%
	3	7	22.6%
	4	6	19.4%
QT	1	4	12.9%
	2	16	51.6%
	3	5	16.1%
	4	6	19.4%
Valid		31	100.0%
Missing		0	
Total		31	
Subpopulation		14 ^a	

Table 4.27b: Pseudo R-Square

Cox and Snell	.872
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Table 4.27c: Likelihood Ratio Tests

Effect	Model Fitting Criteria		
	AIC of Reduced Model	df	Sig.
Intercept	69.039	0	.
DrainageProcess	73.817	9	.007
TransferOilMethod	57.346	9	.709
Quantity	52.196	9	.009

The Table 4.27a illustrates the frequency distribution as percentages for the drainage time, drainage procedure, transfer of oil method, and quantity of coolant fluid drained out from ELVs.

Table 4.27c reveals the multinomial logistic regression equation for the drainage time, which is:

$$Y = 69.039 + (73.817)DrainageProcess + (57.346)TransferOilMethod + (52.196)QuantityofOilDrained$$

and R-square value for the model is 0.872 as seen in Table 4.27b. The value of 0.872 represents a stable and highly fit model since this value is close to 1.

The predictor variables, drainage process and quantity of coolant fluid drained out have a significant ($p < 0.05$) influence on the drainage time as analyzed from the significance column in Table 4.27c. However, the β value obtained for transfer oil method would have a lower effect on the drainage time of coolant fluid from the vehicles.

4.9 Industrial Engineering Methodologies

Industrial Engineering methodologies such as Flow Process Charts, FMEA and Pugh Matrix have been carried out for petrol/diesel from ELVs. Petrol/diesel drainage procedures have been categorized from the plant visits in Canada and responses to online survey received from the recycling companies in Canada.

Petrol/diesel is one of the major components of fluid drainage process. Since, petrol/diesel are highly flammable liquids as discussed in the literature review so, even a slight amount of the fluid left in the fuel tank could result in a huge loss to the company. As a result, precautions need to be taken during their drainage process. Therefore, to understand the process and current equipment used for the removal of petrol/diesel from the vehicle, the local scrap yards in India and the recycling facilities in Canada were visited. The four different drainage methods discovered by visiting the facilities have been discussed below:

4.9.1 Drainage Procedures

Petrol/Diesel drainage procedures involve both manual and automatic methods. The four different drainage procedures have been discussed below:

- I. **Drainage from the fuel drain nut using gravity:** The earlier models of Maruti 800 fuel tanks had a fuel drain nut at the bottom of the fuel tank. The fuel drain nut was easily opened using a wrench of 12 size and fuel was drained out instantly due to gravity. This method drained out the maximum amount of fuel from the tank but is currently out of practice as the automotive manufacturers have redesigned the fuel tanks by removing the nut. However, this nut was observed during the scrapyard visit in India and small scale

recycling facilities in Canada. The design of a drain nut on a fuel tank has currently been observed in Maruti and Tata Motors in India.



Figure 4.17: Petrol/Diesel Drainage Method 1

The picture on the left in Figure 4.17 illustrates the location of the fuel drain nut in a fuel tank i.e. at the lowest most position for maximum fuel drainage. In addition, the picture on the right side depicts the loosening of the drain nut to allow the initiation of the fuel drainage.

II. Using suction method:



Figure 4.18: Petrol/Diesel Drainage Method 2

In this method, the fuel tank filled with petrol/diesel is carefully removed from the bottom of the car using the tools to open the bolts and by cutting the fuel line hose. After the fuel tank has been carefully removed, it is stored in a safe place to prevent any fire explosion. At a later stage, a hose is attached to the fuel line and the worker creates suction by creating a vacuum in the hose to drain out the fuel using gravity and then is stored in small containers such as buckets or bottles as depicted in the figure 4.18 shown above.

III. Suction of fuel from the fuel tank reservoir under the back seat:

In this process, the worker removes the back seat of the vehicle. On successful removal of the back seat, the fuel tank cover is visible to the worker. There are several screws on the fuel tank cover, which are unscrewed by the worker. The worker then removes the fuel pump gauge and inserts a tube into the tank to drain out the petrol/diesel from the vehicle. A suction pump can be used to automatically drain the petrol/diesel or manually by sucking at the other end of the hose the fluid starts to drain out. The petrol/diesel drained out is collected in big buckets and stored to be used again by the company for its own vehicles.

IV. Drill/punch a hole into the fuel tank to drain out petrol/diesel

In this method, the fuel tank is not removed from the vehicle. However, the car is lifted on a lift at a considerable height to provide easy access for the worker. Firstly, the fuel is drained out from the fuel tank using the depollution equipment consisting of a drill/punch attached with a hose, which automatically transfers the fuel from the fuel tank to the storage containers located outside in the yard. In addition, a fuel filter can also be attached during the drainage process to filter the particles and improve the quality of the fuel drained out, before it is stored in the storage container. Later on, the fuel tank is dismantled, stored in the yard for few days to allow vaporization of the fumes from the tank.

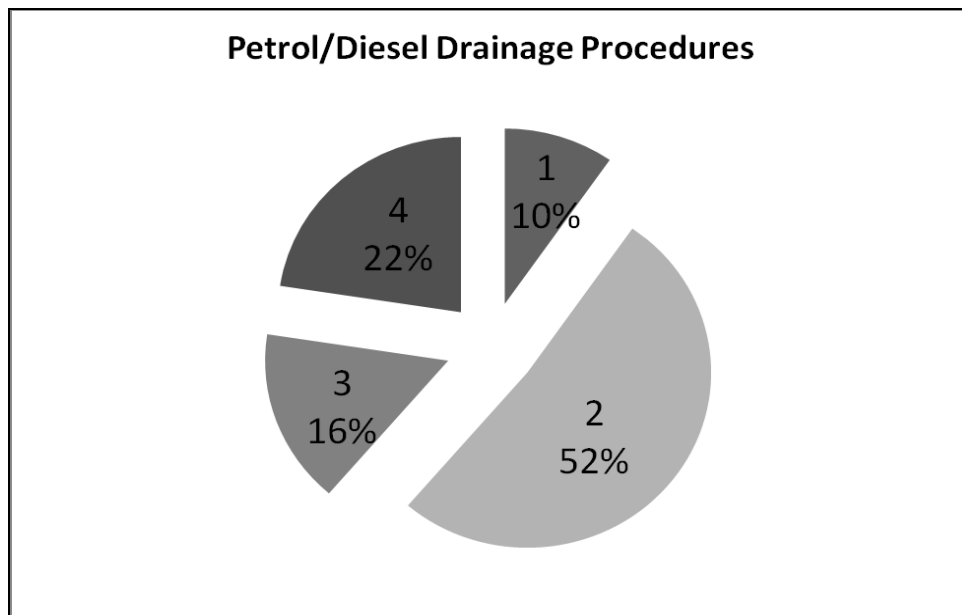


Figure 4.19: Petrol/diesel Drainage Procedures

The results from the survey respondents have been depicted using a pie chart in figure 4.19. It shows that only 10% of the companies are following manual method of drainage using the drain nut located on the fuel tank. However, more than 50% of the survey respondents are draining petrol/diesel from ELVs after the tank has been lowered down and drained using gravity/suction,

which illustrates that this process is widely used even though it is not environmentally friendly and unsafe for the workers. Whereas only 16%, of the companies are draining out petrol/diesel from the fuel tank reservoir located under the back seat. This method is very time consuming and spillages do occur during the manual drainage method. Lastly, 22% of the survey respondents are following automatic drainage procedures by either drilling/punching a hole into the fuel tank while it is mounted on the vehicle.

The information gathered from the survey respondents indicated three different facility configurations. Different process/methods are being practiced for the drainage of petrol/diesel from ELVs, which have been depicted as flow process charts. A flow process map has been prepared illustrating the complete dismantling and shredding process of an ELV as shown in the figure below:

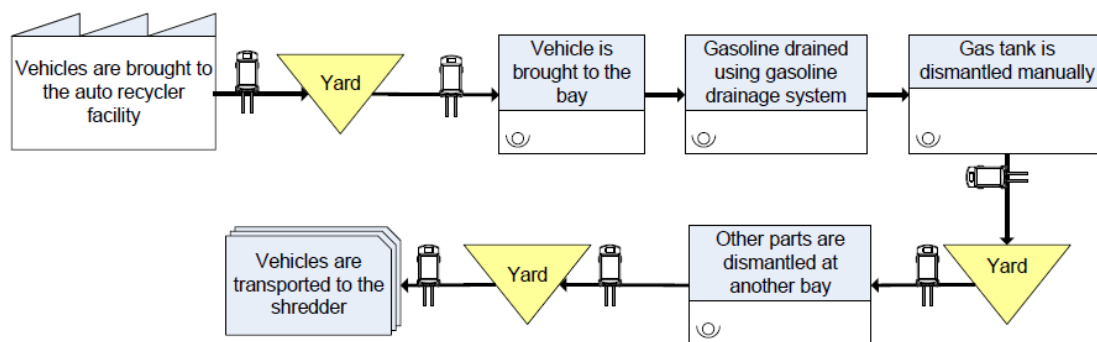


Figure 4.20: Sample Flow Process Map

4.9.2 Facility Types

The first type of facility configuration involves an exclusive bay for the fluids drainage and then the vehicle is transferred to separate dismantling stations for the removal of other parts of the end of life vehicle. The second type of facility configuration demonstrates that all the dismantling of the parts and fluid drainage processes occurs at the same station. However, the fluids are drained out in the beginning of this process using an automatic method. The third facility configuration is similar to the second type while adopting manual drainage methods for the drainage of petrol/diesel from an ELV.

4.9.2.1 Facility Type I

Considering facility type I (F1) map as seen in Appendix – III, it can be observed that the first step in the process involves to bring the vehicles to the auto recycler facility and then stored in a yard until they are processed. The vehicle is then brought to the fluid drainage station with the help of a forklift where all the fluids from the vehicle are drained out at the same bay. Petrol/Diesel in this facility type is drained out by drilling/punching a hole into the fuel tank using depollution

equipment. The depollution equipment is connected to an air suction pump through a hose that drains out the fuel from the fuel tank in a few minutes and stored in huge storage tanks located outside the facility. On successful drainage of the Petrol/Diesel, the worker manually dismantles the fuel tank and leaves it in the yard for fume vaporization to ensure that no fuel residue is left behind since it is very hazardous. The vehicle is then relocated to the yard by a forklift and waits in the queue to enter the dismantling station. After the vehicle enters the dismantling station, other parts such as engine, transmission, electrical wires etc. are removed from the vehicle and inventoried in the warehouse to be sold in future. The vehicles are then stacked together on top of each other after all the parts have been removed and a truckload of vehicles are transported to the shredder for further processing and removal of ferrous and non-ferrous metals from the vehicle.

4.9.2.2 Facility Type II

Similarly, in a facility type II (F2) as shown in Appendix – III, the vehicles are brought to the auto recycling facility and stored in a yard until they are processed. This facility has been designed in such a manner that, it can handle fluid drainage process and dismantling of the vehicle all at the same bay. Once the vehicle is brought into the bay, petrol/diesel is drained by drilling/punching a hole into the fuel tank using portable equipment and transferred to a fuel caddy by using an air pump suction method. Later on, the fuel caddy is re-located to an outside storage area thus allowing access to the fuel collected for the company vehicles. The portable equipment is then moved to a central location in the facility to allow other workers to perform petrol/diesel drainage process. Additionally, after the fuel tank has been dismantled other parts of the vehicle are also pulled out. The vehicle is then stocked up in the yard and finally sent to the shredder.

4.9.2.3 Facility Type III

However, facility type III (F3) as shown in Appendix –III follows a different drainage process. Once the vehicle enters an auto recycler facility, it is stored in a yard using a forklift. After the vehicle is brought into the bay, the worker analyzes the fuel tank and carefully dismantles the fuel-filled tank onto a small caddy. The worker then cuts fuel tank hoses and removes fuel gauge from the fuel tank. Furthermore, the petrol/diesel is drained out using gravity technique and stored in the buckets. The worker finally transfers the fuel from the buckets to huge storage tanks located in the yard. On successful completion of the petrol/diesel drainage process, other parts of the vehicle are dismantled at the same bay. After completely dismantling the vehicle, it is transported to the yard and sent to the shredder for more processing.

4.9.3 Flow Process Charts

Flow process charts are graphical and symbolic representations of work performed. Flow Process charts are widely used in industry to represent the entire sequence of a process. Flow charts were created for all facility types since each facility type follows a different procedure. The following data was collected to complete the flow charts:

- 1) **Distance:** total distance travelled by the worker in that specific task. Since each facility is different, it is unreasonable to obtain measurements for one facility only. Rather, distance was tracked in steps.
- 2) **Quantity:** represents the amount of times the activity was done, i.e. walking done by the worker to obtain tools is one activity and this has been performed 5 times during the process.
- 3) **Time:** represent the time spent on the activity.

Flow Process Charts for Facility Type I (F1) is shown in Appendix – III. The summary shows that a worker in F1 spends most of the time in delay tasks. Flow Process Charts for Facility Type II (F2) is shown in Appendix – III. The Summary shows that a worker in F2 spends most of the operation in delay tasks. Flow Process Charts for Facility Type III (F3) is shown in Appendix – III. The summary of the flow process shows that workers in F3 spend most of the operation in transportation tasks. The comparison between current Facility Types is shown in Appendix – III.

Appendix – III shows that workers in F2 are spending maximum time in Operation tasks, and fewer in Delays, which means that workers are utilized better and spending more time in productive value added tasks, rather than unnecessary delays. This can be due to F2's facility configuration (everything done at one bay). Therefore, the proposed solution should consider the benefit of this facility layout. In terms of Transportation tasks, F2 scored poor due to the added time in transporting equipment. The worker at F3 facility type has been observed to spend more time in transportation and this is caused by the fact that workers have to transfer petrol/diesel frequently to the outside storage tank each time the fluid is drained out from a vehicle.

In summary, Flow Process Charts assisted the time reduction efforts, resulting in F2's facility configuration being more efficient than F1 and F3. Moreover, the analysis of flow process charts has allowed to analyze the current timings of the drainage process at the three facilities and guided to consider for improvements that will be implemented through Failure Mode and Effect Analysis (FMEA).

4.9.4 Failure Mode Effect and Analysis (FMEA)

Failure Mode Effect and Analysis (FMEA) is a tool used to find potential failure modes for each process activity considered. FMEA analysis has been carried out in Microsoft Excel to analyze the impact of environment and ergonomic of the current practices that facilities are following. FMEA is analyzed by calculating the Risk Priority Number (RPN), which represents the risk of the process. The following formula is used:

$$\text{Risk Priority Number (RPN)} = \text{Severity} * \text{Occurrence} * \text{Detection}$$

Appendix – III illustrates the breakdown of the FMEA analysis carried out. The flow process charts developed in the previous section shows the different stages of the process that interact with one another to reach the end of the life cycle of a vehicle. The different process inputs for the FMEA analysis were extracted from the flow process charts to be analyzed and to recommend improvements in the recycling process. Furthermore, for each process step considered the potential failure mode related to the step was found and entered into the table. The FMEA table reveals ‘petrol is transferred to a huge storage tank outside manually’ as one of the important process steps, so a Potential Failure Mode is assigned to the process input i.e. petrol/diesel spillage. The next step involved to determine the effect of spillages and from the literature survey conducted it was found that spillages resulted in soil/groundwater contamination and/or fire. Based on the information available, a severity ranking is used to determine the criticality of the failure mode on the process. Therefore, a severity factor of 5 was assigned to the soli/water contamination on a scale from 1-10. For each failure mode, the possible mechanism and cause of failure are stated. This is an important element of the FMEA analysis since it points the way toward preventive/corrective action. The most appropriate cause for the spillages to occur during the manual transfer of oil to the huge storage tank as observed was obstructions on the way to the tanks located outside. Additionally, the potential cause was assigned an occurrence rate of 2 on a scale from 1-10. The last step involved determining the current controls being followed by the companies to prevent the spillages from occurring. Through the plant visits it was found that, in-order to prevent potential spillages the pathway should be kept cleared from any obstructions and this control method was assigned a high detection rate of 10 as it was not easily detectable. Finally, the Risk Priority Number for each of the process steps was calculated. The RPN is the critical indicator for determining proper corrective action on the failure modes. As a rule of thumb, the smaller the RPN value the better it is for the company. The RPN calculated for the process ‘petrol is transferred to a huge storage tank outside manually’ was:

$$\text{RPN} = (5)\text{Severity} \times (2)\text{Occurrence} \times 10(\text{DetectionRate})$$

$$\text{RPN} = 100$$

The generation of the RPN allowed focusing the attention on solutions to priority items rather than trying to analyze all the failure modes of petrol/diesel drainage from the vehicles. Furthermore, actions were recommended for the process steps with high RPN values to reduce the RPN value. In this case, the recommended action suggested was to have an automatic system of transferring the fuel from the drainage area to the storage tank located outside the facility. The re-evaluated RPN for the process resulted in a reduced value of 10. Therefore, a ninety-percent decrease was calculated by considering the difference in the two RPN values obtained for when ‘petrol is transferred to a huge storage tank outside manually’ process step.

Recommended actions are supported by the FMEA to reduce the risk of potential injuries and failure modes. The table shown below provides a summary of recommended actions and respective percentage decrease in RPN for Petrol/Diesel Spillage Failure Mode.

Table 4.28: Percentage Decrease in RPN for Petrol/Diesel Drainage Process

Recommended Action	Percentage Decrease
Collect petrol/diesel onto a close container automatically	-98.0%
Operate fluid drainage and dismantling at the same station	-87.5%
Automatically transfer petrol/diesel to huge storage tanks outside the facility	-97.0%

The process steps that had significant impact on the current practices have been addressed in the proposed method for the drainage of automotive fluids from ELVs. The failure modes included in the FMEA are the failures anticipated at the design stage of the problem. The benefit of performing the FMEA analysis is to incorporate the recommended actions determined and develop an innovative process for the automotive fluids drainage from ELVs.

The next section reveals the innovative drainage process after taking into consideration the results from Flow Process Charts and FMEA analysis to develop a proposed facility type that accomplishes the goal of the research study.

4.9.5 Proposed Method for Petrol/Diesel Drainage

The responses from the survey and plant visits were analyzed using Industrial Engineering tools such as flow process maps, flow process charts, and FMEA analysis. The analysis has allowed

determining the most appropriate facility type that can be improved by implementing the recommendations from flow process charts and FMEA analysis.

During the analysis stage of the research study, flow process charts and failure mode effect and analysis were performed to determine the detailed steps involved in a petrol/diesel drainage process from the vehicles. From the flow process charts, unnecessary tasks were determined which have been eliminated from the proposed facility type. In addition, the results from FMEA analysis revealed the steps, which required improvements in order to make the fluids drainage process more time efficient, ergonomically safe and environment friendly. Hence, all the process steps required were brainstormed to determine a proposed facility type that proposes a standardized drainage method of petrol/diesel from the vehicles and the dismantling of fuel tank. The flow process map for the proposed facility type can be seen in Appendix – III.

The owner of the vehicle or a forklift brings the end-of-life vehicles or the total-loss cars to the auto-recycling facility. After the vehicle arrives at the facility, it is stored in an open yard and a specific serial number is assigned to the vehicle for record purposes. After the vehicle is brought into the facility, the worker performs an overall analysis of the vehicle and assesses the condition of the re-usable parts that can be stored in the warehouse. The worker lifts up the vehicle to access the fuel tank. The next step involves the decision-making where the worker decides, if he requires the fuel tank or not in order to follow a certain procedure for petrol/diesel drainage from the vehicle. As a result, two different drainage scenarios are available to the worker depending on the decision made.

Scenario 1: In this scenario, the worker has decided that the fuel tank is not required for the inventory purposes. As a result, the proposed petrol/diesel drainage process allows the worker to drill/punch a hole into the fuel tank and then drain petrol/diesel through suction. This scenario could use some depollution equipment for the automatic drainage of petrol/diesel from the vehicles. This scenario results in a time-efficient, environmentally friendly and safe drainage procedure.

Scenario 2: Whereas in this scenario, the worker has decided to save the fuel tank and store it in the warehouse for future purposes. The next step for the worker is to carefully remove the petrol/diesel from the vehicle by manually cutting the fuel line and then drain the petrol/diesel using air suction method to minimize spillages on the floor. In comparison to scenario 1 this process is little more time-consuming, and little spillages may occur during the cutting of fuel line by the worker and pose a little threat to the health of the worker.

On successfully removing the petrol/diesel from the vehicles in both the scenarios, the next stage involves the dismantling of the fuel tank from the vehicle. The worker removes the fuel tank manually by cutting the straps attached around the fuel tank. Moreover, the worker also cuts the

hose connecting the fuel tank and the engine. The fuel tank is dropped to the floor, cut into halves to allow fume vaporization, and stored in a bin to be sent for shredding. Furthermore, the worker continues to work in the same bay to drain the other fluids and dismantle the remaining parts from the vehicle.

On completion of the dismantling process of the vehicle at a bay, the vehicle is transported to the yard using a forklift. The scrap of the vehicle are stacked on top of each other and picked up by the shredder and resulting in an end to the life-cycle of a vehicle.

This proposed facility type has several benefits in comparison to the other facility types determined earlier for the drainage of petrol/diesel from the vehicles. The advantages of the innovative method results in saving workers time, prevents petrol/diesel spillage and soil & water contamination and allows more number of cars to be processed at the facility.

Numerical analysis has been carried out to calculate the drainage time for the proposed drainage method. The results in Table 4.29 illustrate that the improved facility type F4 would reduce the petrol/diesel drainage time to 10.5 minutes in comparison to 13.8 (F1), 20.9 (F2) and 32.1 (F3) facility types. After calculating the differences in the reduction of time as compared to F4, the total time is reduced by 24%, 50% and 67% for F1, F2, and F3 respectively as mentioned in Table 4.29.

In conclusion, if the drainage time is reduced by the proposed method more number of cars can be processed as they are linearly related to each other.

Table 4.29: Comparison of drainage time of F1,F2,F3 with F4

Actions	Current			Proposed	Difference		
	F1	F2	F3	F4	F1	F2	F3
	Time (mintues)						
○ Operation	4.75	5.75	15.57	4.64	-0.11	-1.11	-10.92
⇒ Transportation	0.92	4.10	6.75	0.95	0.03	-3.16	-5.81
□ Inspection	0.33	0.33	0.25	0.16	-0.17	-0.17	-0.09
D Delays	5.90	4.13	5.42	3.33	-2.57	-0.80	-2.08
▽ Storage	0.50	4.50	0.92	0.38	-0.12	-4.12	-0.53
Distance Travelled (steps)	74.00	204.00	472.00	68.00	-6.00	-136.00	-404.00
Total Time (min)	13.80	20.90	32.10	10.50	-3.30	-10.40	-21.60

CHAPTER 5. QUALITATIVE MODELING

5.1 Introduction

This chapter presents the inferences drawn from earlier phases of work in the form of learning issues and their utilization through a qualitative model to develop a proposed methodology for the drainage of automotive fluids from the vehicle. The main techniques for modeling have been validation of the proposed drainage method by using a decision matrix, developing a CAD model and performing breakeven analysis for the proposed drainage method of automotive fluids.

5.2 Methodology for Modeling

The analysis of survey data and plant visits has revealed a number of shortcomings in the drainage procedures of automotive fluids. During the previous phases of the research study, a number of recommendations have been suggested according to the type of fluid drained out. It is however difficult to implement all the suggestions. Therefore, a need is felt for a methodology, which generates an alternate solution to the problem and helps in choosing a set of most effective drainage method. To meet this objective, a qualitative model has been developed in the present research study using decision matrix, development of a CAD model for the proposed drainage method, and break-even analysis.

5.2.1 Validation of the proposed drainage method

5.2.1.1 Decision Matrix

Decision matrix also known as Pugh matrix was designed to perform comparison among the existing solutions and the proposed drainage process. The evaluation criteria were designed in a way that it meets the objective of the project. Hence, the criteria were divided into sub categories such as efficiency, environmental issues and safety of the worker. The comparison for the best practices for petrol/diesel drainage has been depicted by the Pugh matrix in Appendix – III. The current facility type were compared to the proposed facility type (datum) to validate the proposed solution. The comparison was done by assuming the fact that the particular criterion will meet the requirements of the research study. The convention used in the matrix is that: if better than datum (+), same as datum (s) or not as well as datum (-).

The facility types were evaluated for the following criteria's:

- Reduce petrol/diesel drainage time per vehicle
- Must reduce fuel tank dismantling process time

- Must eliminate spillages on the floor
- Draining out maximum amount of fuel from the vehicle
- Providing safe working conditions for the worker

From the Pugh matrix, it was concluded that the proposed drainage method has the maximum number of “+”, as well as the least number of “--”. Hence, Pugh matrix validated the steps involved in the drainage process of fuel from the vehicle.

5.2.1.2 Proposed Drainage Method for Automotive Fluids

As previously mentioned in the proposed facility type F4 the new drainage process would implement the features that current facility types do not have. The features being added to the proposed drainage method (see Appendix – III) have been determined through FMEA, Pugh Chart and Flow Process Charts.

The research study has allowed to develop a proposed drainage method for the drainage of automotive fluids currently being practiced both in India and Canada. The facility type 4 (F4), has been considered as a baseline for this method since it includes most of the recommended features required for an effective drainage process. As a result, a computer-aided design (CAD) model has been prepared by using AUTOCAD 2010 as seen in Figure 5.1 to illustrate the features of the innovative drainage method.

Firstly, it is recommended to have fluids drainage and dismantling of the parts practiced at the same bay and this practice has been observed to be effective during the plant visits and results from the online survey. As illustrated in the Appendix – III, the vehicle arriving at a facility should be lifted up to a certain height to allow easy accessibility underneath the vehicle for the worker. The next step involves the removal of automotive fluids from the vehicle.

Secondly, the worker identifies the location of engine oil, gear oil chamber and drain nut for the removal of coolant fluid from the vehicle. The worker initially decides to drain out oils. In order to drain out engine oil from the vehicle, the worker access the tools required to open the drain nut located on the engine oil chamber. The innovative idea of using a portable trolley to transfer out the used oil directly to the storage tanks located outside the facility can be seen in the figure 5.1. The portable trolley proposed has a rotating arm and funnel shaped at the top is connected to the trolley. Moreover, the portable trolley is directly connected to a control box on the left as seen in the figure below. The control box has several levers that can be turned ‘on’ depending on the fluid to be drained out. In the case of engine oil, after the worker has loosened the engine oil drain nut, the worker can immediately turn on the lever specifically designed for engine oil. The engine oil

would be automatically transferred to huge used oil storage tanks located outside through hoses installed in the facility.

After the engine oil drainage process has begun, the worker can use the same portable trolley for the drainage of gear and brake oil from the vehicle. The worker turns 'on' the gear oil lever located on the control box and the gear oil drain nut is opened into the funnel and collected in the used oil storage tank located outside the working area. Furthermore, the worker inserts the suction hose into the brake oil container and completely drains out the brake oil to the used oil tank.

Similarly, the worker to drain out coolant fluid from the vehicle can use another portable trolley. The same trolley used for the drainage of engine and gear oil is not preferred since it would result in a mixing of oils with the coolant fluid, which is considered as not a safe drainage method and violates the rules and regulations of the automotive recycling industry as discussed in the literature review section. In-order to remove the coolant fluid, the worker can either open the radiator drain nut, or cut the radiator hose, or insert a piercing tool into the connecting radiator hose. The lever for the coolant fluid is turned 'on' by the worker to drain out the coolant automatically to the huge storage tank located outside.

Furthermore, to drain out petrol/diesel from the vehicle a slightly differently designed equipment can be used. The worker locates the location of fuel tank in the vehicle. The worker grabs the portably trolley as seen in the figure below. This portable trolley has a transparent filter attached to the equipment rod for screening the quality of petrol/diesel drained out. In-order to drain maximum petrol/diesel from a vehicle, FMEA analysis recommended the use of drill/punch for the drainage method. So, a drill/punch that is ATEX certified is used for the safe removal of petrol/diesel is located at the top of the connecting arm as seen in the figure below. This would allow a drill/punch to pierce into the fuel tank after the worker has applied pressure to it. This portable trolley is also connected through a hose to the control box as seen in the figure below. As soon as the worker drills a hole into the fuel tank, the worker can examine the quality of the fuel from the transparent filter and turn 'on' the appropriate lever located on the control box for the drainage of petrol/diesel from the vehicle. As a result, the fuel is completely drained out without any spillages on the floor and in an effective manner. Lastly, the worker dismantles the empty fuel tank, cuts into halves and stores them in the large bin for shredding purposes.

The portable trolleys can be used at other workstations once the worker has finished draining out the fluids from a vehicle. This allows for optimization of the resources available in a company, minimizes the fixed costs associated with drainage procedure and maximizes the output from the end of life vehicles.

In conclusion, the proposed CAD model has implemented best practices observed during the plant visits along with addition of innovative ideas as one of the standardized methods for the drainage of automotive fluids. The proposed method would certainly be beneficial for the auto-recyclers as they can process more vehicles in a day, improve their process efficiency, ensuring working conditions are environmentally friendly and safe for the workers.

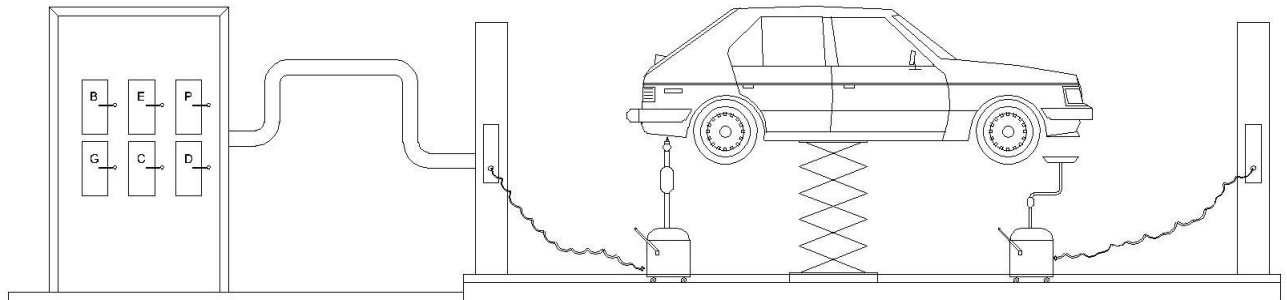


Figure 5.1 CAD Model Designed for the Proposed Drainage Method

5.2.1.3 Break-Even Analysis

The break-even cost for automotive fluids drainage is defined as the point where the total cost of revenue generated after selling the fluids drained equals the cost of the equipments purchased for the drainage process. This report shows the results of the process breakeven analysis.

The process breakeven analysis calculates the number of years required to recover all fixed expenses associated with the drainage process from the vehicles. The analysis calculates the years the drainage process must be executed by a company to generate a net profit that recovers the fixed cost incurred during the setup of the facility. This calculation is critical for any business owner, because the break-even point is the lower limit of profit when determining margins. There are several types of costs considered to conduct a breakeven analysis for the automotive fluids drainage from an ELV, which are:

- Fixed costs,
- Variable costs,
- Sales revenue, and
- Total costs.

Fixed Costs

The fixed costs are those that are invariable, and that must be paid regardless of the level of production. These costs are determined after the design process has been finalized by the company to enter into the business activity while considering the design perspectives prepared using the

CAD model. The fixed cost includes the expenses related to the materials and equipments used to setup a bay where the drainage process can be executed by a worker which are as follows:

- 1) Cost of lift,
- 2) Pump to transfer petrol/diesel from the vehicle to storage tank located outside the facility,
- 3) Pump to transfer used oil from the vehicle to separate storage tank located outside,
- 4) Pump to transfer used coolant fluid to the storage tank located outside,
- 5) Estimate of drill machine required for the drainage of petrol/diesel from a vehicle,
- 6) Funnel used for the collection of used oils,
- 7) Storage tank for petrol/diesel located outside the working area,
- 8) Storage tank for used oils located outside the facility,
- 9) Storage tank for used coolant fluid located outside the facility,
- 10) Levers attached on the control box to control the drainage of fluids,
- 11) Type of pipe and its cost used for the transfer of petrol/diesel from the working area to the storage tank,
- 12) Type of pipe and its cost used for the transfer of used oil from the working area to the storage tank,
- 13) Type of pipe and its cost used for the transfer of coolant fluid from the working area to the storage tank, and
- 14) Installation cost and other expenses during setup of the facility.

The above mentioned parameters were determined after carefully analyzing the CAD model prepared for the proposed drainage process and ensuring that the objectives of the research study were fulfilled. These parameters were then noted down for the data collection from the companies to perform breakeven analysis. The relevant costs required to execute breakeven analysis were obtained from the following places:

- Automotive Companies i.e. Toyota and Mercedes in Chandigarh,
- Durga Bhai Corporation in Chandigarh,
- Scrap dealers in Chandigarh,
- Jagir Industries in Chandigarh, and
- Recyclers Source in Canada.

Firstly, two types of lifts i.e. hydraulic and scissor lifts were observed during the plant visit at Pioneer Toyota in Chandigarh as seen in Figure 5.2. However, it was observed that the scissor lift was less preferred as compared to hydraulic lifts since the lower body of the vehicle was not accessible to the worker due to the design of the lift. The hydraulic lifts allowed full access to

underneath the vehicle and could lift a load up to a maximum of four tonnes. The costs determined were as follows:

- Hydraulic Lift: Rs. 1,50,000
- Scissor Lift: Rs. 2,00,000



Figure 5.2: Hydraulic and Scissor Lift

The next stage involved in determining the type of suction pump required for the transfer of fluids from the vehicle to the storage tanks located outside the facility. To determine the type of pumps various shops were visited in Chandigarh and it was found that rotary gear pumps are required for the viscous fluids due to the higher viscosity of the oils. The advantages of using a rotary gear pump are that they are compact, produce low-noise levels, efficient and economical for daily purposes. The details of the rotary gear pump chosen were obtained from Durga Bhai Co. and are as follows:

- Model: HGN-100,
- Inlet-Outlet Size: 1 x 1 inch,
- Output Capacity: 50 litres per minute, and
- Cost: Rs. 14,000.

The Figure 5.3 displays the rotary gear pump that has been chosen for the suction of used oils, coolant fluid and diesel from the vehicles. The costs associated for each of the fluids has been included in the fixed cost calculated for the drainage system designed.



Figure 5.3: Rotary Gear Pump

In addition, the suction pump required for petrol is specially ordered considering the volatile nature of petrol and therefore the costs associated with that pump is slightly higher as compared to the previously mentioned rotary gear pump. The cost for the suction of petrol is Rs. 28,000.

Furthermore, appropriate type of pipe is required to transfer the fluid from the suction pump to the storage tank located outside the facility. From the visit to Toyota and Mercedes it was determined that Galvanized Iron material pipe was used for the viscous fluids. The cost of GI 1.0 inch pipe was determined by visiting other shopkeepers in Chandigarh and it was found to be Rs. 165/meter. The length of GI pipe required from the working bay to the storage tank was approximately 100 feet.

Therefore, the cost for the GI pipe in feet has been calculated as follows:

1 meter = 3.281 feet

Cost of 1 feet of GI pipe = $(165/\text{meter}) / 3.281 = \text{Rs. } 50/\text{feet}$

Therefore, cost of 100 feet of GI pipe = $\text{Rs. } 50 * 100 = \text{Rs. } 5000$

The GI pipe with a length of 100 feet has been attached to the petrol/diesel, oils and coolant suction pumps. The total cost for the pipes have been added to the total fixed cost.

The control box design has been developed as a CAD model shown in Figure 5.4. The control box includes six levers for the fluids along with an option to be turned 'on' and 'off' accordingly. The pumps have been assembled behind the control box in such a manner that they are used only when the lever on the control box has been turned 'on' by the worker. The control box is connected to the portable trolleys using the GI pipes and the pumps are further hard-wired to the storage tanks

located outside. The setup cost for the control box along with levers is approximately Rs. 5000. This setup allows the direct transferring of fluid from the portable equipment to the containers outside thus minimizing the spillages and improving the time-efficiency of the drainage process.

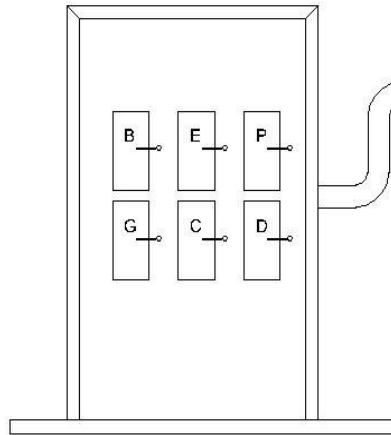


Figure 5.4: Control Box Design for Proposed Drainage Method

The next step was to determine the cost of drill used for the drainage of petrol/diesel located on the portable trolley as seen in the CAD model. The drill required needed to be safe as it could result in a catastrophic accident. One of the widely used drill machines for the petrol/diesel drainage is designed by SEDA, a leading supplier of recycling products in US and UK. The SEDA's remarkable tank drilling machine drills through the metal and plastic tanks and sucks out the fuel without spilling a drop on the floor as seen in Figure 5.5. In addition, the drilling machine is entirely air-powered and ATEX certified. The ATEX certified ensures that it is fire and explosion proof. In-order to determine the cost of SEDA machine, Recycler's Source in Canada was contacted. The price for the drilling equipment is approximately \$6000 that is equivalent to Rs. 3,00,000.



Figure 5.5: Drill for fuel tank

Moreover, to collect the oils and coolant fluid a funnel shaped apparatus has been designed as seen in the CAD model. The portable trolley with a funnel on the top is connected to an air suction system that creates vacuum once the lever is turned on. The total cost of the pneumatic box, flexible air pipe and the funnel is approximately Rs. 5000 as seen in Figure 5.6 and costs were obtained during the plant visit to Pioneer Toyota in Chandigarh.

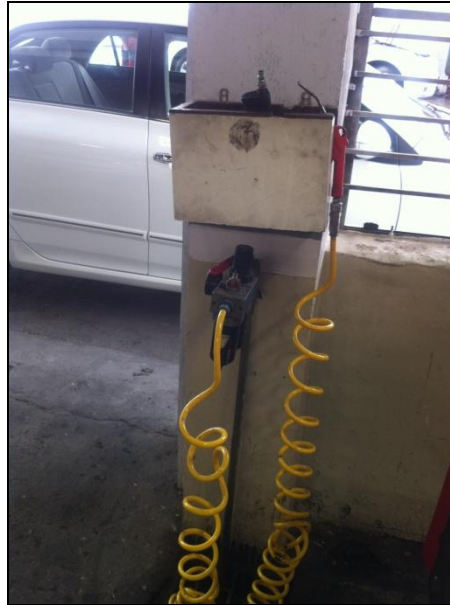


Figure 5.6: Pneumatic Pump

Lastly, the storage tanks required for the collection of petrol/diesel, used oils and coolant fluid needed to be studied in depth. The literature review revealed that Stainless Steel material should be used for the storage tanks due to its beneficial characteristics. The storage tanks have been decided to be placed outside the working area to prevent any fatalities from occurring and resulting in a longer length of pipe connecting the suction pump and the storage tank. The storage tanks have an opening at the top allowing for the cleaning of the fluids after few years of usage. In addition, an outlet pipe and a nozzle have also been designed into the design of the storage tank for extracting the fluids from the storage tanks. The capacity of the tanks is 3000 lts and the cost estimate has been obtained from Jagir Industries in Chandigarh. There are various types of stainless steel material available in the market but the most preferred for the automotive fluids is Type 202 and Type 304.

The properties of Stainless Steel 202 are:

- Type: Austenitic Standard
- Common Name: Chromium-Manganese-Nickel Steel
- Composition (Wt. %) : Mn (7.5-10); Cr (17-19); Ni (4-6)
- Density: $7.8 \times 1000 \text{ kg/m}^3$
- Elongation % = 40

- Specific Heat = 500 J/kg-K

The properties of Stainless Steel 304 are:

- Type: Austenitic Standard
- Common Name: Chromium-Nickel Steel
- Composition (Wt. %) : Mn (2); Cr (18-20); Ni (8-10.5)
- Density: $8.0 \times 1000 \text{ kg/m}^3$
- Elongation % = 40
- Specific Heat = 500 J/kg-K

The Type 304 is widely used for food and milking industry due to its high corrosion resistance and excellent toughness even at high temperatures. This results in increasing the cost of the product manufactured by using Type 304 Stainless Steel. However, for the break-even analysis Type 202 Stainless Steel has been used for the manufacturing of storage tanks for petrol, diesel, used oils and coolant each with a capacity of 3000 lts. The cost estimates for the tanks are shown in Table 5.1.

Table 5.1: Storage Tank Cost for Stainless Steel Type 202

Stainless Steel Type 202	Cost (3000 lts capacity)
Petrol	Rs. 50,000
Diesel	Rs. 50,000
Used Oil	Rs. 43,000
Coolant fluid	Rs. 42,500

The petrol and diesel storage tanks have anti-rusting and anti-spark coating done to prevent any explosions from occurring in case of any accidents at the facility. This coating has resulted in an additional cost of Rs. 7000 for their manufacturing costs.

Table 5.2: Storage Tank Cost for Stainless Steel Type 304

Stainless Steel Type 304	Cost (3000 lts capacity)
Petrol	Rs. 85,000
Diesel	Rs. 85,000
Used Oil	Rs. 80,000
Coolant fluid	Rs. 80,000

The costs obtained for Steel Type 304 are approximately double the cost obtained for Type 202 as analyzed from the Table 5.1 and 5.2.

The total fixed costs have been calculated separately for petrol and diesel vehicles. The total fixed costs also includes installation and other expenses costs occurred during the setup of the working facility such as labor required, mechanical tools, and has been approximated to Rs. 1,00,000.

Summary of the total fixed costs for the petrol vehicle is shown in Table 5.3.

Table 5.3: Summary of Total Fixed Costs for Petrol Vehicles

Type of Fixed Cost	Cost (Rs.)
Hydraulic Lift	1,50,000
Petrol Engine Suction Pump	28,000
Oil Pump	14,000
Coolant Fluid Pump	14,000
Drilling machine	3,00,000
Funnel box with pneumatic pump for oil and coolant	5,000 + 4,500 = 9,500
3000 lts petrol storage tank	50,000
3000 lts used oil tank	43,000
3000 lts coolant fluid tank	42,500
Control box with levers	5,000
100 feet pipe for petrol	5,000
100 feet pipe for used oil	5,000
100 feet pipe for coolant fluid	5,000
Installation + other expenses	1,00,000
Total fixed costs	7,71,000

Summary of total fixed costs for the diesel vehicle is shown in Table 5.4. The difference between Table 5.3 and Table 5.4 is the cost of diesel and petrol suction pump, which is Rs. 14,000.

Table 5.4: Summary of Total Fixed Costs for Diesel Vehicles

Type of Fixed Cost	Cost (Rs.)
Hydraulic Lift	1,50,000
Diesel Engine Suction Pump	14,000
Oil Pump	14,000
Coolant Fluid Pump	14,000
Drilling machine	3,00,000
Funnel box with pneumatic pump	5,000
3000 lts diesel storage tank	50,000
3000 lts used oil tank	45,000
3000 lts coolant fluid tank	45,000
Control box with levers	5,000
100 feet pipe for diesel	5,000
100 feet pipe for used oil	5,000
100 feet pipe for coolant fluid	5,000
Installation + other expenses	1,00,000
Total fixed costs	7,57,000

Variable Costs

The variable costs are the costs that are recurring as the time progresses. These costs are incurred in proportion to the level of output obtained. For the drainage process, labor charges and electricity charges are the variable costs associated.

The labor charges are increasing on a yearly basis according to the information obtained from Toyota and Mercedes. According to the data collected the average salary of a worker in the companies was Rs. 10,000 per month. Considering 30 days on an average in a month, the workers were off for 4 days and had 1 optional day off thus resulting in 25 days of working days in a month. The next step involved the calculation of daily labor rate, which has been calculated as:

No. of working days (in a month) = 25

Labor rate = Rs. 10,000 / month

Labor rate (in days) = Rs. 10,000 / 25 = Rs. 400 / day

Furthermore, the electricity consumption for the running of the machinery in the working area is also considered as a variable cost. The electricity consumption and rate varies with time as analyzed from the data obtained from the two companies. The electricity consumed depends on the number of bays, the mechanical equipments and the lightning in the working area. The average expenditure of an existing facility for the operation of vehicles resulted in the range of Rs. 45000 – 50,000 monthly. The next step involved the calculation of electricity charges on a daily basis and results in the value of:

No. of days in a month = 30

Average electricity charges per month = Rs. 48000

Average electricity charges per day = Rs. 48000 / 30 = Rs. 1600 / day

Summary of total variable costs associated for the drainage of automotive fluids from ELVs is shown in Table 5.5.

Table 5.5: Summary of Total Variable Costs

Type	Costs (Rs.) per day
Labor Rate	400
Electricity Charges	1600
Total Variable Costs (TVC)	2000

However, for the calculation of breakeven analysis the total variable cost has been tabulated while considering the number of days on an increment of 5 days.

Sample Calculation:

The TVC for 5 days = Rs. 2000/day x 5 days = Rs. 10,000

TVC for 10 days = Rs. 2000/day x 10 days = Rs. 20,000

Therefore, the resulting table is as shown in Table 5.6.

Table 5.6: Total Variable Costs predicted for 100 days

Days	Total Variable Costs (Rs.) in thousands
0	0
5	10

10	20
15	30
20	40
25	50
30	60
35	70
40	80
45	90
50	100
55	110
60	120
65	130
70	140
75	150
80	160
85	170
90	180
100	200

Sales Revenue

The revenue cost is the amount that is received from the sale of the fluids collected during the drainage process. The revenue generated depends on the quantity of petrol/diesel drained out from the vehicle along with the quantity of used oil drained out. However, in order to determine the average petrol/diesel and used oils drained out from the vehicles, the data gathered during the information gathering phase has been reconsidered to determine the average quantity of the drained fluids. Another important consideration that has been kept in mind is the number of working bays and the number of cars processed daily. From the statistical analysis it has been determined that working bays and number of cars processed are linearly correlated, therefore the influence of working bays on the cars processed has been eliminated to determine the average number of cars

that can be processed in a company. In addition, the total quantity of oil drained out includes the quantity of engine oil, gear oil, brake oil and power steering oil.

Following calculations illustrate the average quantity of petrol/diesel, used oil drained out from the vehicle and the number of cars processed on a daily basis.

Average quantity of petrol/diesel drained out

The quantity of fuel drained out from the vehicle has been categorized into four categories as:

- i. 5 – 30 litres of petrol/diesel from the vehicle,
- ii. 5 – 45 litres of petrol/diesel from the vehicle,
- iii. 10 – 50 litres of petrol/diesel from the vehicle, and
- iv. 2 – 80 litres of petrol/diesel from the vehicle.

The next step involved the addition of the frequencies of companies that drained out the respective quantity of fuel from the vehicles depending upon the procedure chosen. From the statistical analysis, it was analyzed that if the company had chosen automatic method over the manual method for the drainage procedure then more amount of petrol/diesel was drained out from the vehicle. The inferences from the statistical analysis have been correlated for the calculation of revenue for the petrol/diesel.

The Table 5.7 illustrates the frequency of the fuel drainage from the vehicle and the total quantity of petrol/diesel obtained from the vehicles.

Table 5.7: Average quantity of petrol/diesel drained from the vehicles

Petrol/Diesel drainage category	Frequency	Average quantity drained out (litres)	Total (litres)
5 – 30 litres	3	$= 25/2 = 12.5$	$= 12.5 * 3 = 37.5$
5 – 45 litres	16	$= 40/2 = 20$	$= 20 * 16 = 320$
10 – 50 litres	5	$= 40/2 = 20$	$= 20 * 5 = 100$
2 – 80 litres	7	$= 78/2 = 39$	$= 39 * 7 = 273$
Total fuel drained out (litres)			$= 37.5+320+100+273$ $=730.5$
Average fuel drained out (litres)			$=730.5/31 = 24$

The above table illustrates the total amount of petrol/diesel that was drained out from all the vehicles that were processed. However, to determine the average quantity of petrol/diesel drained out, the total amount of the fuel is divided by the total number of companies from which the data was collected i.e. 31. The output obtained is the average unit of petrol/diesel from a vehicle.

Average quantity of petrol/diesel drained = $730.5 / 31 = 23.56$ litres i.e. approximately 24 litres.

The 24 litres obtained are for both the petrol/diesel vehicles that arrived at the facility for the recycling purposes. In-order to split them evenly the average quantity of fuel drained out is also split evenly i.e. 12 litres each of petrol and diesel for the calculation of breakeven point for petrol and diesel vehicles respectively.

In addition, the scrap dealers mentioned that they are paid Rs. 20/litre for the petrol and Rs. 12/litre for amount of diesel drained out from the fuel tank. These costs have been used to calculate the revenue generated from the extracted petrol/diesel from the vehicle.

Revenue generated for petrol = 12 litres/car x Rs. 20 /litre = Rs. 240 /car

Revenue generated for diesel = 12 litres/car x Rs. 12 /litre = Rs. 144 /car

Similarly, the calculations have been performed to calculate the average quantity of engine oil, gear oil and brake oil from the vehicles.

The Table 5.8 depicts the average quantity of engine oil drained out from the vehicles considering the data gathered during the plant visits.

Table 5.8: Average quantity of engine oil drained from the vehicles

Engine Oil drainage category	Frequency	Average quantity drained out (litres)	Total (litres)
0 – 6 litres	7	= $6/2 = 3$	= $7 * 3 = 21.0$
0 – 6.5 litres	9	= $6.5/2 = 3.25$	= $9 * 3.25 = 29$
0 – 7 litres	7	= $7/2 = 3.5$	= $7 * 3.5 = 25$
0 – 8 litres	8	= $8/2 = 4$	= $8 * 4 = 32$
Total engine oil drained out (litres)			= $21+29+25+32$ =107
Average engine oil drained out (litres)			= $107/31 = 3.5$

Similarly, the average quantity of gear oil drained out from the vehicles is shown in Table 5.9.

Table 5.9: Average quantity of gear oil drained from the vehicles

Gear Oil drainage category	Frequency	Average quantity drained out (litres)	Total (litres)
0 – 6 litres	9	$= 6/2 = 3$	$= 9 * 3 = 27.0$
0 – 6.5 litres	7	$= 6.5/2 = 3.25$	$= 7 * 3.25 = 22.75$
0 – 7 litres	8	$= 7/2 = 3.5$	$= 8 * 3.5 = 28$
0 – 8 litres	7	$= 8/2 = 4$	$= 7 * 4 = 28$
Total gear oil drained out (litres)			$= 27+22.75+28+28$ $= 105.75$
Average gear oil drained out (litres)			$= 105.75/31 = 3.4$

Summary of the quantity of oils drained out from the vehicle depending upon the drainage procedure chosen by each company is summarized in Table 5.10.

Table 5.10: Total quantity of different oils drained from the vehicles

Type of used oil	Quantity drained out from a vehicle (litres)
Engine Oil	3.5
Gear Oil	3.4
Brake Oil	2.5
Power Steering Oil	0.6
Total	10

The information gathered by visiting the facilities during the data collection process revealed the total revenue generated from the used oil by selling it to the local recycling agencies. The calculation below illustrates the price per litre for the used oil:

Average cost of new engine oil for Toyota vehicles = Rs. 260/ litre

Selling Price of used oils = Rs. 5000 per 250 litre drum

Toyota sells one used oil drum of the quantity 250 litres for the price of Rs. 5000. Moreover, the company also charged Rs. 500 for each drum sold by the company to the agency.

Net revenue = Rs. 5000 – 500 = Rs. 4500 for 250 litres

Net revenue for each litre of used oil = Rs. 4500 / 250 = Rs. 18 / litre

The value of Rs. 18/ litre for the used oil has been considered for the calculation of breakeven point for the proposed drainage method.

Calculation of revenue for the used oil drained out from the vehicles by considering the proposed drainage method.

Average quantity of oils drained out = 10 litres

Price of used oil = Rs. 18 / litre

Therefore, revenue generated = Rs. 18/litre x 10 litres = Rs. 180

The total revenue generated has been divided into two scenarios. The first scenario considers the petrol vehicles that were drained out in the working bay. The oils were also drained simultaneously during the petrol drainage process. The other scenario considers the diesel vehicles along with the drainage of used oils from the vehicle. The total revenue generated has been calculated independently for both the scenarios. In addition, the breakeven points have also been calculated independently for the petrol and diesel vehicles.

The table 5.11 summarizes the breakdown of the total revenue costs per car for the petrol vehicles.

Table 5.11: Total Revenue Costs for Petrol vehicles

Type of Fluid	Revenue (Rs.) per car
Petrol	240
Used Oils	180
Total Revenue	420

The table 5.12 summarizes the breakdown of the total revenue costs per car for the diesel vehicles.

Table 5.12: Total Revenue Costs for Diesel vehicles

Type of Fluid	Revenue (Rs.) per car
Diesel	144
Used Oils	180
Total Revenue	324

The next step involves the determination of number of cars processed daily for the automotive fluids drainage.

Number of working hours in a day for each company = 7 hours

Actual working time per day in a company in minutes = 7 hours x 60 mins/hour = 420 mins

Now, it is required to determine the total time taken by a vehicle at each bay to calculate the number of cars that can be processed. From the time study analysis it has previously been determined that the proposed drainage equipment for petrol/diesel requires 10.5 minutes. However, if the other oils are drained out simultaneously during the fuel drainage using automatic methods then the time required is approximately 11 minutes. In total, the time required for completely draining out all the automotive fluids from the end-of-life vehicle results in = 10.5+11 = 21.5 minutes per car.

Number of cars processed daily = 420 minutes / 21.5 minutes per car = 20 cars (approximately)

Hence, the total revenue costs for petrol and diesel vehicles have been calculated as:

Total revenue costs for petrol vehicles per day = Rs. 420 per car x 20 cars = Rs. 8400

Total revenue costs for diesel vehicles per day = Rs. 324 per car x 20 cars = Rs. 6480

Sample Calculation for petrol vehicle:

The TRC for 5 days = Rs. 8400/day x 5 days = Rs. 42,000

TRC for 10 days = Rs. 8400/day x 10 days = Rs. 84,000

Therefore, the resulting table is shown in Table 5.13.

Table 5.13: Total Revenue Costs predicted for Petrol Vehicles up to 140 days

Days	Total Revenue Costs (Rs.) in thousands
0	0
5	42.00
10	84.00
15	126.00
20	168.00
25	210.00
30	252.00

35	294.00
40	336.00
45	378.00
50	420.00
55	462.00
60	504.00
65	546.00
70	588.00
75	630.00
80	672.00
85	714.00
90	756.00
95	798.00
100	840.00
105	882.00
110	924.00
115	966.00
120	1008.00
125	1050.00
130	1092.00
135	1134.00
140	1176.00

Similarly, the total revenue costs table for diesel vehicle is as shown below.

Sample Calculation for diesel vehicle:

The TRC for 5 days = Rs. 6480/day x 5 days = Rs. 32,400

TRC for 10 days = Rs. 6480/day x 10 days = Rs. 64,800

Table 5.14: Total Revenue Costs predicted for Diesel Vehicles up to 190 days

Days	Total Revenue Costs (Rs.) in thousands
0	0
5	32.4
10	64.80
15	97.20
20	129.60
25	162.00
30	194.40
35	226.80
40	259.20
45	291.60
50	324.00
55	356.40
60	388.80
65	421.20
70	453.60
75	486.00
80	518.40
85	550.80
90	583.20
95	615.60
100	648.00
105	680.40
110	712.80
115	745.20
120	777.60

125	810.00
130	842.40
135	874.80
140	907.20
145	939.60
150	972.00
155	1004.40
160	1036.80
165	1069.20
170	1101.60
175	1134.00
180	1166.40
185	1198.80
190	1231.20

After successfully determining all the required costs for the calculation of breakeven analysis, breakeven point has been calculated for petrol and diesel vehicles independently. The break-even points for the vehicles are different since the total fixed costs and the total revenue costs for them have a slight difference in their values.

Break-Even Point = Total Fixed Costs / (Total Revenue Costs – Total Variable Costs)

For Petrol Vehicles:

Break-Even Point (BEP) = 771000 / (8400 – 2000) = 120.5 days

The approximation of 120.5 days is equal to 4 months at which the company neither gains nor loses any money for the investment made.

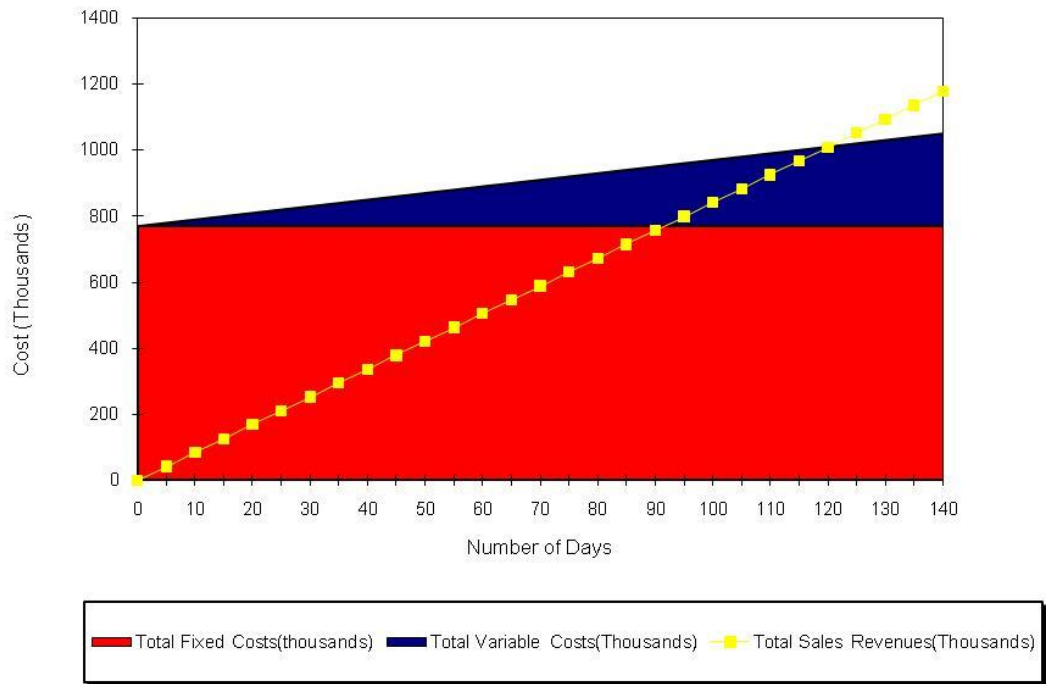


Figure 5.7: Breakeven point for petrol vehicles

The red area illustrates the total fixed costs incurred during the setup of the drainage system in a facility. The blue area indicates the total costs for the proposed drainage method.

Total costs = total fixed costs + total variable costs

The graph in Figure 5.7 illustrates the break-even point calculated graphically using Microsoft Excel and if observed carefully the sales revenue linear line intersects the total costs line at 120 mark approximately. Hence, the results obtained theoretically have been validated by graphical results as seen in the above figure. The profit begins to increase linearly after the four months of using the equipments to drain the automotive fluids from ELVs.

Similarity, the break-even point has been calculated both mathematically and graphically for the diesel vehicles that arrived at the facility for the drainage of automotive fluids from the vehicles.

For Diesel Vehicles:

$$\text{Break-Even Point (BEP)} = 757000 / (6480 - 2000) = 169 \text{ days}$$

The BEP of 169 days is approximately equal to 6 months after which the company starts to make profits.

The mathematical days calculated have been graphically verified by observing the intersection point of sales revenue line and total costs line in the Figure 5.8.

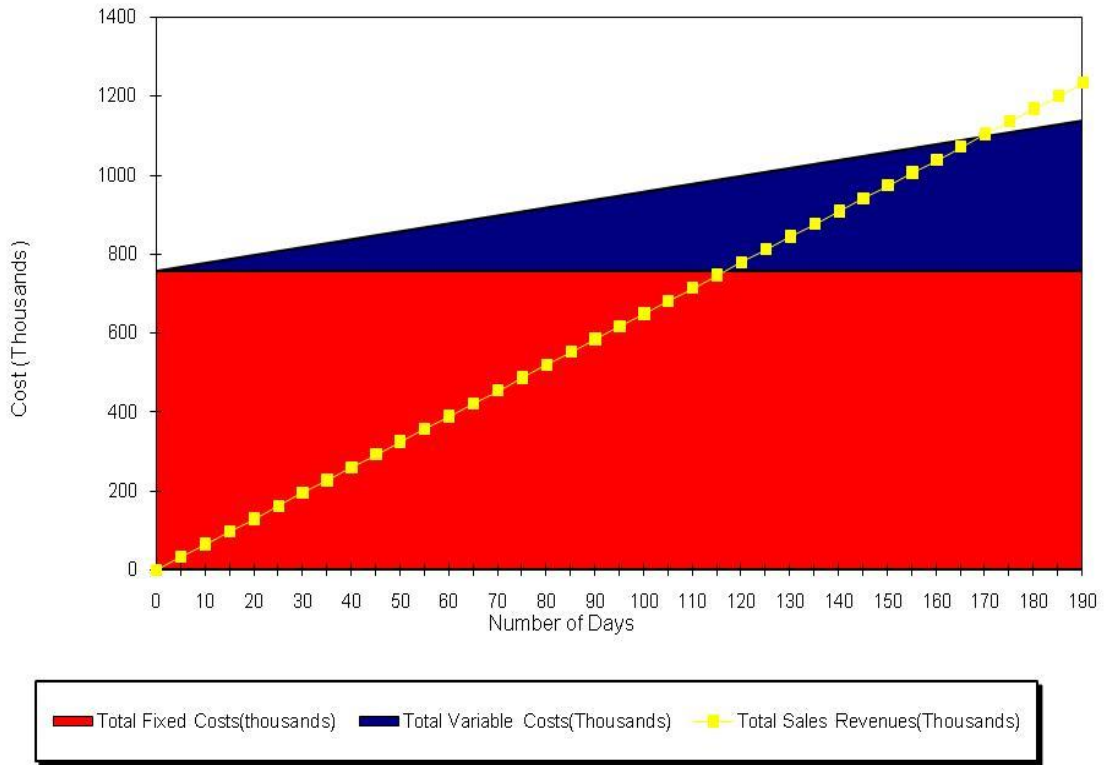


Figure 5.8: Breakeven point for diesel vehicles

CHAPTER 6. CONCLUSION

6.1 Introduction

The summary of the research covers the methods adopted, salient features, and tools and techniques used in the study. Further, the results of the survey and plant visits and the inferences drawn from them have been presented. Based on the results and the findings, conclusions have been drawn and recommendations have been made. The limitations along with the scope for future work are covered in the sections of this chapter.

6.2 Results and Major Findings

The various results have been derived on the basis of quantitative analyses performed on the data gathered during the initial stages of the research study. The main findings are presented as follows:

6.2.1 Results of the Survey

Considering the present situation of recycling in India, there is a need for change in respect of recycling and recovering materials from these vehicles, which are at the end of their useful life. In India, such vehicles are sold as scrap to the local scrap-dealers where the parts are dismantled and sold separately. However, due to the lack of modern techniques, the process is highly polluting and affects the health of the workers. This is an issue, which calls for immediate and careful attention from the government and all stakeholders, before it burgeons into a major national problem.

Out of 300 questionnaires sent, 30 responses were received from Canadian recyclers and visits were made to 31 facilities to collect and validate the data collected. Out of the total data, collected 58% were from Canada and the rest 42% was gathered by visiting the automotive service centers in Chandigarh and Patiala. The observations made from Canadian online survey were authenticated by personally visiting most of the recyclers. Actual visits to the facilities proved to be very knowledgeable and favorable for the research study. In addition, Cronbach's Alpha coefficient has been calculated for convergent validity to assess the internal reliability of the factors studied. The results from SPSS revealed in coefficient values > 0.8 , thus indicating high reliability of questions considered in the questionnaire.

Recycling has become an important part of preserving the environment and in the automotive industry, recyclers ensure that all reusable parts and fluids are removed from the end-of life vehicles (ELVs) and stored in a safe manner. The fluid removal is the initial stage of the dismantling process after the vehicle arrives at the recycling facility.

6.2.2 Drainage Procedure Evaluation

The drainage procedure is one of the important independent factors considered during the research study. From the responses of the survey, four different drainage methods have been determined for the oils and petrol/diesel. The drainage procedures determined follow either manual, semi-automatic, fully automatic methods or a mix of manual and automatic methods. The method chosen by the worker for the drainage of fluids from ELVs have a significant effect on the quantity of fluid drained out, drainage time and the number of cars processed daily. A significant correlation has been exhibited between drainage procedure and quantity of oil drained out from the vehicle while keeping transfer of oil method as controlled factor for 95% confidence interval. The correlation coefficient value suggests that if an automatic method is chosen as drainage procedure, then maximum amount of oil can be drained out from the vehicle as compared to manual methods. Moreover, the correlation analysis has also verified that number of cars processed daily is greatly influenced by the drainage procedure. As a result, the more advanced technical equipments are used for the drainage procedure; more beneficial it is for the company. The partial correlation and regression analysis have verified that among the three independent factors, drainage procedure has the greatest impact on the drainage time, quantity of oil drained out and the number of cars processed at a facility.

6.2.3 Transfer of oil method evaluation

Along with the fluid drainage procedure, one of the other input factors that have significant impact on the dependent factor is the method of transferring used fluids from the drums/pans to the huge storage tanks located outside the facility. After the fluids have been collected in the drums, they are shifted to the huge tanks approximately 3000 litres in size and are then sent to the fluids recycling facilities for the recycling purposes. The comparison between the manual methods observed and automatic transfer of oil methods reveal that more spillages occur during the manual methods; it contaminates the environment and effects the health of the worker as compared to other three methods.

The statistical and industrial analysis proposed that the fully automatic transfer oil methods eliminates the environmental hazards, safety of the workers and makes the process very time-efficient as compared to the other three methods.

6.2.4 Number of working bays evaluation

Furthermore, the number of working bays has also been considered as one of the important input factors for the research study. The Pearson's correlation analysis between the number of working

bays and the cars processed daily have illustrated a positive significant association between them with an r-value of 0.571 for engine oil. Therefore, it can be inferred that on increasing the number of working bays at a facility, it would result in an increase in the number of cars processed due to their strong linear correlation.

Moreover, the various regression models developed for engine oil, gear oil and coolant fluid have considered number of working bays as one of the independent factors to determine the impact of working bays on the quantity of fluid drained, drainage time, and cars processed daily. The regression models reveal that number of working bays has a significant contribution on the output factors considered. The statistical values obtained have justified the practically observed relationship between the cars processed for oils drainage and number of working bays.

6.2.5 Proposed Drainage Method

The information gathered from the survey respondents indicated three different facility configurations for the automotive fluids drainage from end-of-life vehicles. For the drainage of petrol/diesel, an improved facility type was developed considering the necessary steps performed by the worker and recommendations of FMEA analysis. This proposed facility type saved workers time, prevented petrol/diesel spillage and environmental contamination. After doing detailed analysis it has been determined that improved facility type F4 would reduce the petrol/diesel drainage time to 10.5 minutes in comparison to 13.8 (F1), 20.9 (F2) and 32.1 (F3) facility types. The F4 was compared to the three existing facility configurations and it was validated by the Pugh analysis that F4 is the best facility configuration among the other facilities. As a result, CAD model has been prepared for the proposed drainage method illustrating the advanced technical equipments such as drill machine for the fuel tank, huge stainless steel storage tanks, portably trolleys with a direct link to the control box and storage tanks located outside. Therefore, the proposed drainage method would prevent any workplace injuries; make the workplace ergonomically safe and environment friendly and the drainage process would become time-efficient.

Lastly, the breakeven analysis has allowed us to study the fixed costs associated with the purchase of technical equipments required for the proposed drainage method. In addition, the variable costs and revenue costs have also been calculated to determine the break-even point for petrol and diesel vehicles. The analysis has revealed a breakeven point of 120 days for petrol vehicles and 169 days for the diesel vehicles, which implies that the company starts earning profit after the break-even point.

In conclusion, the proposed method would certainly be beneficial for the auto-recyclers as they can process more vehicles in a day, improve their process efficiency, ensuring working conditions are environmentally friendly and safe for the workers.

6.3 Limitations of the study

The main limitations of the study are as follows:

- The study has been limited to automotive service centers in the state of Punjab (in northern region of India),
- The data collected for the factors drainage time and quantity of fluids drained out have been considered on an average basis rather than actual figures,
- The exact facility layouts have not been studied in detail to develop the proposed drainage method, and
- The ergonomics design layout for the worker has not been considered in depth during the study.

6.4 Scope of Future Work

- The item measures identified for various constructs have been considered to be of equal importance in the study, however in actual situations, some item measures may be more important than other factors. The study can be extended by reconsidering those items and attaching weight age factor to those items through qualitative techniques. An illustrative study could be carried out by considering the drainage procedure as the most weighted factor in comparison to other input factors of the study to evaluate the effect on output factors.
- The study can be confined to one company in India to study the different drainage procedures followed for the various models of vehicles of that specific company. A comparison study can be performed to determine if there exists any difference in the drainage procedures from state to state in India.
- Another extension of this research study could be a comparison study performed by comparing the drainage methods after dividing the manufacturers into three segments i.e. small, medium and luxury vehicles.
- A detailed study can also be carried out to study the environmental and health issues related to the drainage of automotive fluids from the end-of-life vehicles.

The Indian automotive recycling industry still lacks an innovative environment in terms of technological equipment and regulations required for the processing of recycling industry. Further, government should provide funds to engineering institutes to carry out research in this recycling field and come up with a solution for the small units at the regional level since the number of vehicles being manufactured are increasing at a high rate. The importance of 'achieving and sustaining competitiveness in the long run' in the automotive industry needs to be realized by the Indian Government immediately. The long-term benefits should be analyzed and proper rules and regulations regarding the life of the vehicles should be made aware to the public and save the natural resources for future generations to come.

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APPENDIX - I



Re-usable parts at local scrap dealer in India



Oil drums posing environmental hazard



Unhygienic work conditions at dismantling facilities in India



Huge storage tanks for used fluids in open area and inventoried parts

Licensed Drivers and Motor Vehicle Registrations by Type of Vehicle 1986 – 2005 in Canada**(in Thousands)**

	Licensed Drivers	Passenger Automobiles	Commercial Vehicles	Motorcycles
1986	16,226	11,586	3,285	465
1987	16,927	11,686	3,659	448
1988	17,155	12,086	3,850	400
1989	17,592	12,380	3,962	378
1990	17,718	12,622	4,000	359
1991	18,090	12,578	3,516	350
1992	18,465	12,781	3,461	339
1993	18,843	12,925	3,455	337
1994	19,243	13,131	3,510	330
1995	19,327	13,192	3,535	320
1996	19,964	13,251	3,620	312
1997	20,148	13,515	3,684	319
1998	20,744 ^e	13,887	3,767	334
1999	20,934	16,538	722	274
2000	20,593	16,832	739	311
2001	20,879	17,055	729	318
2002	21,163	17,543	724	350
2003	21,436	17,755	740	373
2004	21,673	17,920	752	409
2005	21,937	18,124	786	443

APPENDIX – II

Sample Questionnaire – 1

Appendix 4: Sample Questionnaire

Interviewer :

Date/time:

Hello, my name is... I'm working on behalf of The British Museum. The Museum is continually seeking to improve the standard of its galleries. To help them do this we are seeking the views of visitors to the HSBC Money Gallery. We would be grateful if you could spend 4 or 5 minutes answering some questions.

1. *How many times have you previously visited The British Museum?*

None **G** 1-5 **G** more than 5 **G**

2. *When was the last time you visited?*

Within last 6 months **G** Within last year **G** 1-3 years **G** More than 3 years ago **G**

3. *Are you visiting the Museum:*

Alone **G** With 1 other **G** 2-4 others **G** 5 or more others **G**

4. *Did you know about the Money Gallery before you visited the Museum?*

Yes **G** No **G** (If yes, go to 5, if no go straight to 6)

5. *How did you hear about the Money Gallery?*

Newspaper **G** Poster **G** Recommendation from someone **G** Internet **G** Other (please state)

6. *Approximately how long have you spent in the gallery?*

Passing through **G** 1-5 minutes **G**
5-10 minutes **G** 10 to 15 minutes **G** More **G**

7a. *Could you see all of the objects clearly?*

Yes **G** No **G** (If yes go to 8, if no go to 7b)

7b. *Why not?*

8. *How easy was it to understand the panels and labels with the objects?*

Very easy **G** Quite easy **G** (go to 9a)
Neither easy nor difficult **G** (go to 10)
Quite difficult **G** Very difficult **G** (go to 9b)

9a. *What made the panels and labels easy to understand?*

9b. *What made the panels and labels difficult to understand?*

10. *Are you aware of any publications linked to this gallery?*

Yes **G** No **G**

11a. *Are you aware that a gallery leaflet is available for use with the HSBC Money Gallery?*

Yes **G** No **G** (If yes go to 11b, if no go to 12)

11b. *Did you buy it?*

Yes **G** No **G** (If yes go to 11c, if no go to 12)

11c. *Did you find the gallery leaflet:*

Very useful **G** Quite useful **G** Not particularly useful **G** Not useful at all **G**

12. *If you were describing this gallery to a friend, which three words would you use?*

bright useless exciting uncomfortable fun relevant noisy boring cheerful
uninteresting good for kids special airless interesting doesn't relate to me attractive
hard to understand

13. *What, if anything, do you find particularly attractive or appealing about the gallery?*

14. *It is perfectly acceptable to find that there are some things you did not like about the gallery. Would you be willing to tell me something you did not like about the gallery?*

Sample Questionnaire – 2

Sample Information Audit Questionnaire

[COMPANY NAME] INFORMATION AUDIT QUESTIONNAIRE

Thank you for participating in the *[company name]* information audit. If you have any questions regarding the completion of this questionnaire please contact *[name, position, location]* by phone *[extension number]* or email *[email address]*.

Please submit the completed questionnaire by *[date]*.

PERSONAL DETAILS

(these details are required for communication purposes only and will not be disclosed)

NAME:

POSITION:

BUSINESS UNIT/DIVISION:

CONTACT DETAILS

TELEPHONE:

EMAIL:

INSTRUCTIONS FOR COMPLETING THE QUESTIONNAIRE

This questionnaire is in electronic format to facilitate its completion and to enable the responses to be automatically prepared for analysis.

Question 1.1 - Please type your response in the space provided, which will expand as you type.

Questions 1.2 to 1.4 - Please type your responses in the appropriate columns of each table. Use your TAB key to create additional lines in the tables where necessary.

Questions 1.5 and 1.6 - Rate each item by placing a cross in the relevant box.

CURRENT INFORMATION ACQUISITION, USE AND GENERATION

Your responses to these questions will provide data relating to the types of information that you use to perform your tasks. It will also provide data that will enable the mapping of information flows within the organization and between the organization and external environment.

1.1 Please describe the tasks that you perform, and describe the information that you need to complete your tasks successfully?

TASK	INFORMATION REQUIRED
Task 1	

1.2 Where do you currently get this information? Please list all resources, whether print, electronic or personal. Please rate the importance of the resource to the task it supports on a scale from 1-5

1 - not presently used or no perceived benefits

2 - provides indirect or minor support

3 - contributes directly to the task but not essential

4 - provides significant benefits or adds value

5 - critical

RESOURCE	TASK NUMBER	SOURCE	FORMAT	IMPORTANCE (1-5)

1.3 What reports or other types of information does your business unit or section make available to other sections of the organization, or to entities outside the organization?

RESOURCE	PROVIDED TO (BUSINESS UNIT / SECTION / EXTERNAL ENTITY)	FORMAT	FREQUENCY

1.4 How does the information you get compare with what you need to complete your tasks? (ie ideally what would you like to have that is not currently available to you). Use the scale from 1-5 to indicate the importance of the required resource.

- 1 - not task-specific - of general benefit
- 2 - to provide indirect or minor support
- 3 - to contribute directly to the task but not essential
- 4 - to provide significant benefits or added value
- 5 - critical

TASK	REQUIRED RESOURCE	IMPORTANCE (1-5)

1.5 Please rate the importance of the following characteristics when choosing/using information resources.

	1 Unimportant	2	3 Important
Accessibility/availability/convenience	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Accuracy	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Adequacy / relevance	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Comprehensiveness	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Cost	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Currency	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Delivery method	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Technical accuracy	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Timeliness	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Other <i>(please specify)</i>			

1.6 Please rate the importance of the following resources that are made available by the Information Unit.

- 1 - don't use
- 2 - provides indirect or minor support to business unit tasks
- 3 - contributes directly to business unit tasks but not essential
- 4 - provides significant benefits or added value to business unit tasks
- 5 - critical

Please complete this questionnaire by *[date]* and **SUBMIT**. If you have any questions about how to complete it, please contact *[person]* by phone *[phone number]* or email *[email address]*.

Thank you

[name]

[position title]

[date]

Primary Questionnaire for the research study

Please tick the correct answer after reading the description of the question

In-order to drain the fuel out from the car there can be several options.

- i. The car could be lifted up and then equipment can be used to drain the fluids out.*
- ii. The car could remain on the ground and the worker slides under the car and uses a bucket to collect the fluids from it.*
- iii. If there's any other method please mention the details about it so that it can be considered*

1. Current procedure
 - a. Lift up the vehicle
 - b. Worker slide underneath the car
 - c. Other

According to the procedure chosen previously for draining the fluids from the car, which fluids are being drained out and please mention the time required for each of the fluids approximately. Fluids could be such as (petrol and diesel, engine oil, coolant oil etc.) . if any other fluids except the ones mentioned below are also being drained out please mention it as well.

2. Which fluids are being drained out? How much time is required for their drainage?
 - a. Petrol and Diesel
 - b. Engine oil
 - c. Brake Fluid
 - d. Transmission oil
 - e. Coolant
 - f. Windshield washer fluid
 - g. Power steering fluid
 - h. Other

***Draining of fuel** (i.e. petrol and diesel) from the ELV's requires a specific technology or an equipment to drain them out efficiently. Considering the existing systems being implemented in UK, USA, Canada and other Asian countries following technologies have been developed.*

***Drain:** in this method the port outlet underneath the car is opened and the fluid is collected in a bucket or a container and transported into a bigger container afterwards.*

***Suction:** in this method technologically advanced equipment is attached to the outlet of the fuel tank, and with the help of hoses and vacuum suction all the fuel is sucked out from the tank and transported directly to the big containers.*

***Drilling the tank:** In this method a portable drilling machine is used. The drilling machine is placed under the car (after being lifted up) and a hole is drilled into the fuel tank and fuel is*

extracted out using hoses. In addition, filters can also be attached to the machine to purify the fuel being extracted.

Pouring the fluid: This is a manual method in which the fuel tank is removed from the bottom of the car. After it has been removed the fuel pump is carefully removed from the tank and the fuel is extracted by pouring the fuel into buckets/containers. After the containers are filled they are transported to the bigger containers.

Please specify the method used at your facility so that facility types can be determined to implement the characteristics of the beneficial facilities into the proposed solution.

3. What kind of technology the facility uses to drain the fluid?
 - a. Drain
 - b. Suction
 - c. Drilling the tank
 - d. Pouring
 - e. Other

After the successful drainage of the fluids it is very essential to find out the possible outcomes/deliverables of the vast amount of fluid drained out from the cars. Since many cars are being processed daily and there would be enough amount of fluid gathered it would be quite essential to make its full utilization in-order to conserve the fluids.

4. What does the facility do with the fluid?

Fluid	Store	Reuse	Recycle	Flush	Other
Petrol/Diesel and Diesel					
Engine oil					
Brake Fluid					
Transmission oil					
Coolant					
Windshield washer fluid					

Power steering fluid					

The facilities vary in size i.e. small, medium or big. Number of cars processed annually decides the size of the facility.

Small: *less than 1000 cars/yr.*

Medium: *1000-5000 cars/yr.*

Large: *more than 5000 cars/yr.*

5. What's the size of the facility and workspace?

Considering the time required for the fluids drainage from the cars, how many cars does the company process in one day on average?

As some of the cars require longer time for the drainage, as a result we require the average cars processed/day.

6. How many cars per day on average?

The workers required for the dismantling of the cars need to be trained in-order to work efficiently. So, is your company following any standard procedures or training methods for the new hired workers to provide them the essential training for the job being performed.

7. Are there standard procedures/documents for new hires?

- f. Yes
- g. No

Considering that the facilities have been running for a while, if any injuries of the workers have been reported. Injuries could occur as a result of oil spill, health issues related to workers when they drain out the fluids from the car, minor or any major industrial accidents related with fluid drainage. Workplace injuries are also possible caused due to the repetitive tasks performed by them.

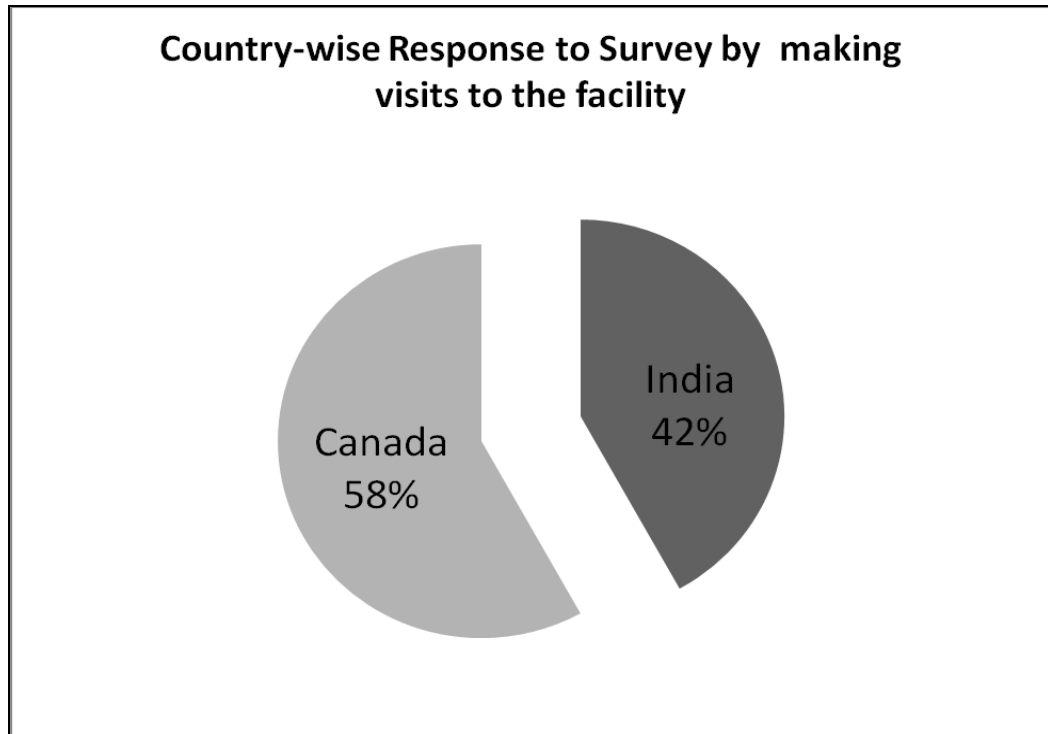
If any economical or relevant data can be provided would help us perform our ergonomic and economic study analysis for the fluid drainage process.

8. Does the facility have any previous data on the accidents/injuries while the worker was draining the fluid or due to the oil spills or containers?
- h. Yes
 - i. No

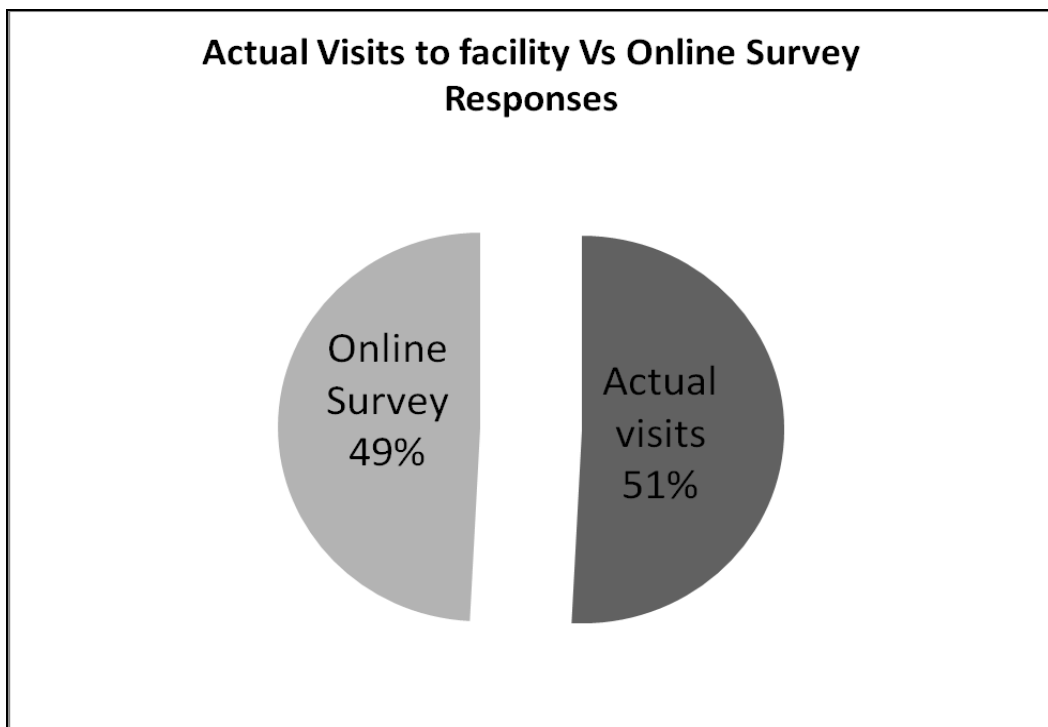
Any workplace injuries caused by the repetitive posture?

- a. Yes
- b. No

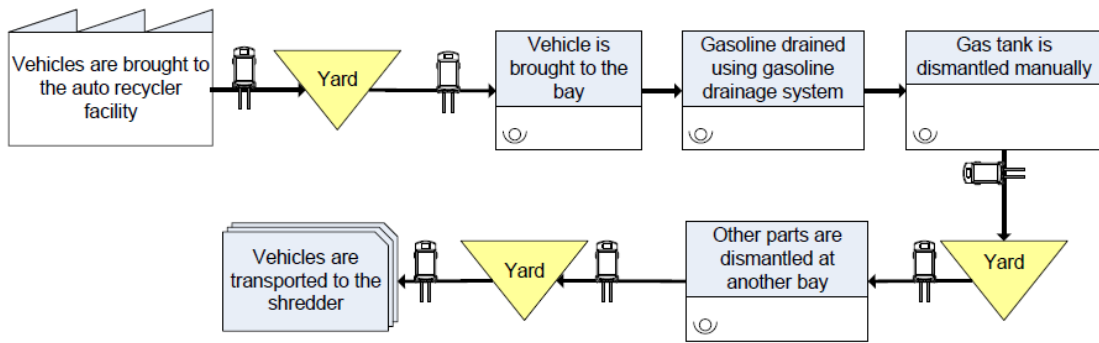
APPENDIX – III



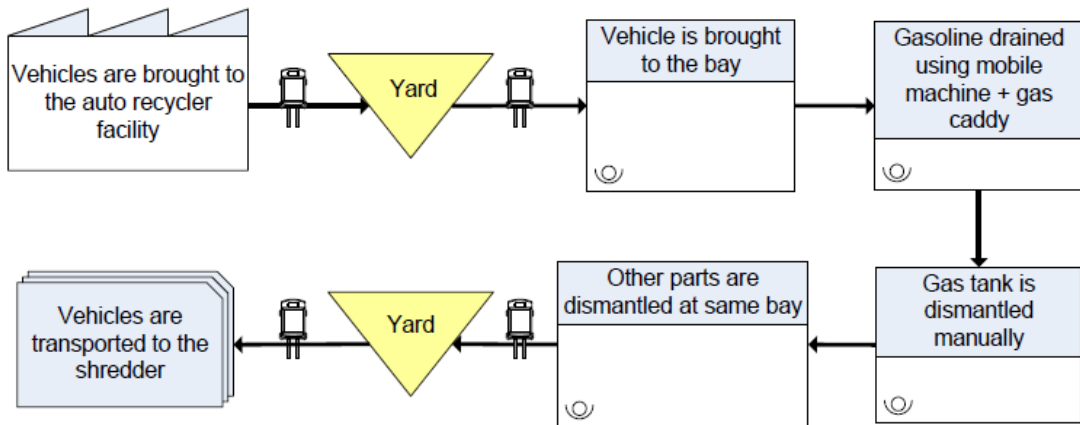
Country-wise Response to Survey by visiting the facilities



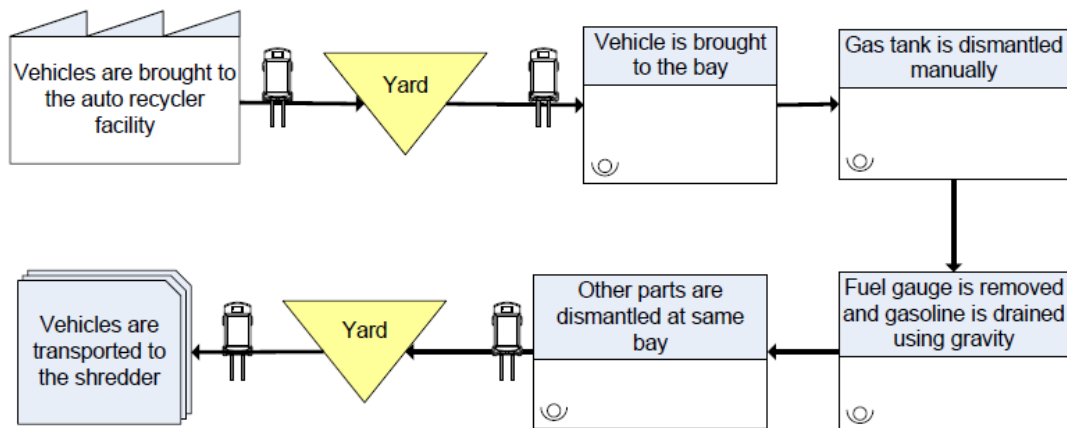
Response comparison to actual visits to the facility Vs Online Survey



Facility Type I



Facility Type II



Facility Type III

Flow process for current facility types

Tasks	F1				F2				F3			
	#	%	Time	%	#	%	Time		#	%	Time	%
Operation	15	46%	4.8	38%	17.2	46%	5.8	31%	59	58%	15.6	54%
Transportation	10	30%	0.9	7%	10.7	28%	4.1	22%	34	33%	6.8	23%
Inspection	2	6%	0.3	3%	2	5%	0.3	2%	1	1%	0.3	1%
Delays	4.8	15%	5.9	48%	4.8	13%	4.1	22%	6	6%	5.4	19%
Storage	1	3%	0.5	4%	3	8%	4.5	24%	2	2%	0.9	3%
Total actions	32.8				37.7				102			
Distance	74				204				472			
Total Time (min)	13.8				20.9				32.1			

Flow Process Chart for Facility Type I

FLOW PROCESS CHART		Number 1	Page No. 1	No. Of Pages 1							
SUMMARY											
Actions	Present			Proposed			Difference				
	No.	%	Time	No.	%	Time	No.	%	Time		
○ Operation	15	48%	4.7533	18	52%	2.79	3	8%	2.74		
⇨ Transportation	10	30%	0.9167	9.5	28%	5.7	-0.5	-3%	55.783		
□ Inspections	2	6%	0.3333	2	6%	1.0	0	0%	9.3867		
⏸ Delays	4.8	15%	5.9	4	12%	2.00	-0.8	-3%	194.12		
▽ Storage	1	3%	0.9	1	3%	2.3	0	0%	22.94		
Total Actions	32.8			34.5			1.7				
Distance Travelled (steps)			77			62.5			-14.5		
Total Time (mins) 10% allowance			13.77			10.5			-3.27		
Details of Present Method - Facility Type 1											
	Operation	Transportation	Inspections	Delays	Storage	Distance (step)	Quantity	Total distance (step)	Time (sec)	Total Time	Notes
1	○	⇨	□	⏸	▽		1	0	20	20	
2	○	⇨	□	⏸	▽		1	0	50	50	
3	○	⇨	□	⏸	▽	5	1	5	5	5	
4	○	⇨	□	⏸	▽		1	0	5	5	Find lower point of gas tank
5	○	⇨	□	⏸	▽	5	1	5	5	5	
6	○	⇨	□	⏸	▽		1	0	5	5	
7	○	⇨	□	⏸	▽		1	0	10	10	
8	○	⇨	□	⏸	▽		1	0	120	120	Simultaneous activity
9	○	⇨	□	⏸	▽		1	0	5	5	
10	○	⇨	□	⏸	▽	5	1	5	5	5	
11	○	⇨	□	⏸	▽	5	1	5	5	5	
12	○	⇨	□	⏸	▽		1	0	15	15	Depends on workers experience
13	○	⇨	□	⏸	▽	5	5	25	5	25	
14	○	⇨	□	⏸	▽		5	0	5	25	Varies each time for different tools
15	○	⇨	□	⏸	▽	3	4	12	15	60	
16	○	⇨	□	⏸	▽		1	0	55	55	
17	○	⇨	□	⏸	▽		1	0	5	5	Spills may occur
18	○	⇨	□	⏸	▽	10	1	10	30	30	Already outside
19	○	⇨	□	⏸	▽	10	1	10	10	10	
20	○	⇨	□	⏸	▽		1	0	50	50	
21	○	⇨	□	⏸	▽		0.2	0	130	26	Operator may drive the forklift
22	○	⇨	□	⏸	▽		0.8	0	130	104	
23	○	⇨	□	⏸	▽		0.8	0	130	104	

Flow Process Chart for Facility Type II

FLOW PROCESS CHART		Number 1	Page No. 1	No. Of Pages 1							
SUMMARY											
Actions	Present			Proposed			Difference				
	No.	%	Time	No.	%	Time	No.	%	Time		
○ Operation	17.2	48%	3.75	18	52%	278.64	0.8	7%	272.89		
⇨ Transportation	10.7	28%	4.1	9.5	26%	96.7	-1.2	-1%	52.6		
□ Inspection	2	5%	0.3333	2	6%	9.72	0	0%	9.3867		
Ⓚ Delays	4.8	13%	4.1333	4	12%	200.02	-0.8	-1%	195.88		
▽ Storage	3	8%	4.9	1	3%	23.04	-2	-6%	12.94		
Total Actions	37.7			34.5			-3.2				
Distance Travelled (steps)			204	63.5			-140.5				
Total Time (mins)			20.9	10.5			-10.39				
Details of Present Method - Facility Type 2											
	Operation	Transportation	Inspection	Delays	Storage	Distance (steps)	Quantity	Total Distance (steps)	Time (secs)	Total Time	Notes
1	○	⇨	□	Ⓚ	▽		1	0	20	20	
2	○	⇨	□	Ⓚ	▽		1	0	50	50	
3	○	⇨	□	Ⓚ	▽	5	1	5	5	5	
4	○	⇨	□	Ⓚ	▽		1	0	5	5	Find lower point of gas tank
5	○	⇨	□	Ⓚ	▽		0.5	0	60	30	
6	○	⇨	□	Ⓚ	▽		0.5	0	30	15	
7	○	⇨	□	Ⓚ	▽		0.3	0	160	48	Unnecessary
8	○	⇨	□	Ⓚ	▽	68	0.7	45	120	90	Unnecessary
9	○	⇨	□	Ⓚ	▽	34	0.3	11	120	40	Unnecessary
10	○	⇨	□	Ⓚ	▽		1	0	30	30	
11	○	⇨	□	Ⓚ	▽		1	0	5	5	
12	○	⇨	□	Ⓚ	▽		1	0	15	15	
13	○	⇨	□	Ⓚ	▽		1	0	120	120	
14	○	⇨	□	Ⓚ	▽		1	0	5	5	
15	○	⇨	□	Ⓚ	▽		1	0	23	23	
16	○	⇨	□	Ⓚ	▽	5	1	5	30	30	
17	○	⇨	□	Ⓚ	▽	34	2	68	120	240	Unnecessary
18	○	⇨	□	Ⓚ	▽		0.2	0	180	36	Unnecessary
19	○	⇨	□	Ⓚ	▽		0.2	0	60	12	Unnecessary
20	○	⇨	□	Ⓚ	▽	5	1	5	5	5	
21	○	⇨	□	Ⓚ	▽		1	0	15	15	Depends on worker experience
22	○	⇨	□	Ⓚ	▽	5	5	25	5	25	
23	○	⇨	□	Ⓚ	▽		5	0	3	15	Varies each time for different tools
24	○	⇨	□	Ⓚ	▽	3	4	12	15	60	
25	○	⇨	□	Ⓚ	▽		1	0	55	55	
26	○	⇨	□	Ⓚ	▽		1	0	5	5	Spills may occur
27	○	⇨	□	Ⓚ	▽	10	1	10	30	30	Already outside
28	○	⇨	□	Ⓚ	▽	10	1	10	10	10	
29	○	⇨	□	Ⓚ	▽		1	0	50	50	
30	○	⇨	□	Ⓚ	▽		1	0	50	50	Operator may drive the forklift

Flow Process Chart for Facility Type III

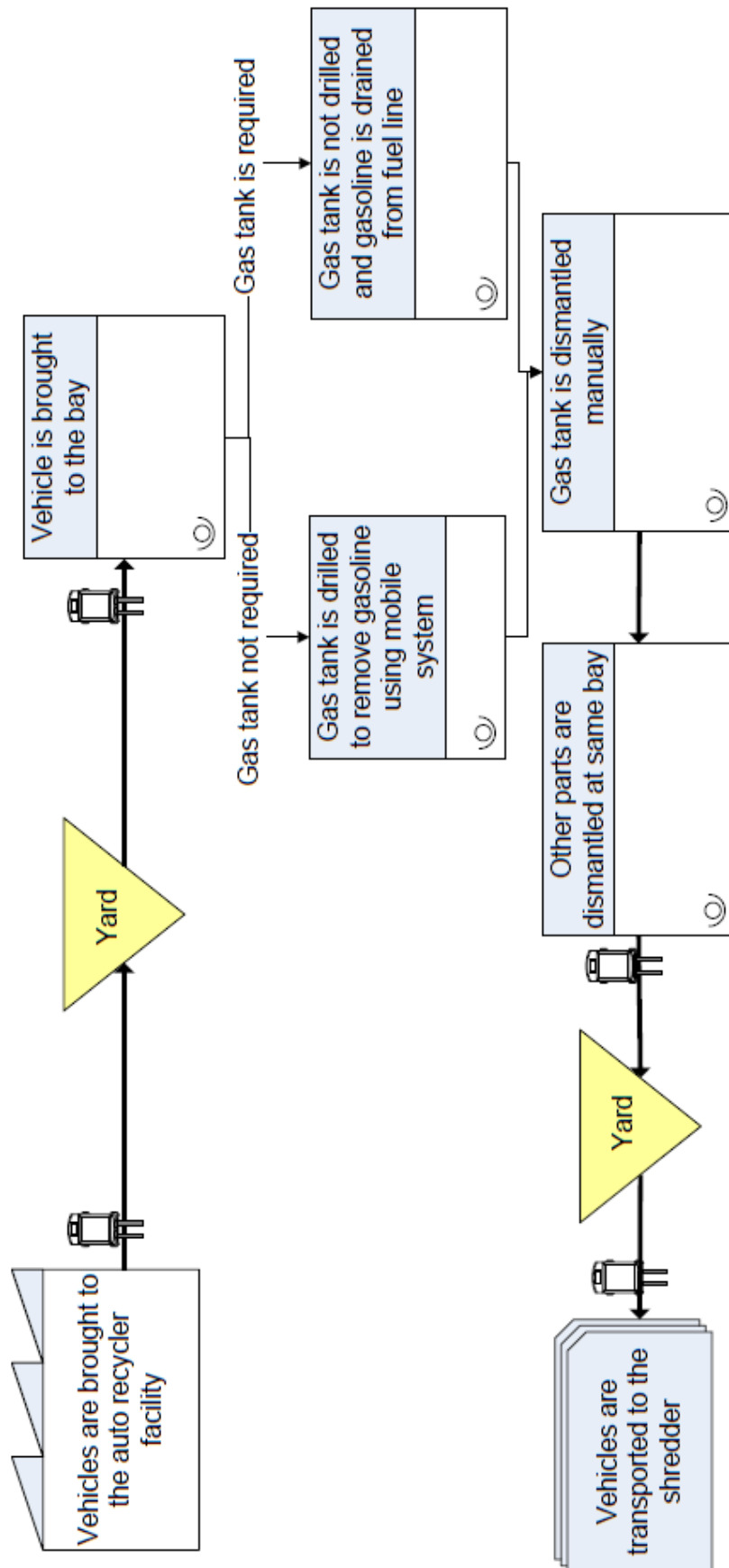
FLOW PROCESS CHART		Number 1	Page No. 1	No. Of Pages 1							
SUMMARY											
Actions	Present			Proposed			Difference				
	No.	%	Time	No.	%	Time	No.	%	Time		
○ Operation	39	98%	15.57	38	92%	278.94	-41	-6%	269		
⇨ Transportation	34	82%	6.75	9.5	28%	56.7	-24.5	-6%	90		
□ Inspection	1	2%	0.25	2	6%	9.72	1	5%	9		
D Delays	6	6%	5.42	4	12%	200.02	-2	6%	196		
▽ Storage	2	2%	0.92	1	3%	23.04	-1	1%	22		
Total actions	322					34.5			-67.5		
Distance Travelled (steps)	472					63.5			-408.5		
Total Time (mins)	3208					10.5			-21.58		
Details of Present Method - Facility Type 3											
	Operation	Transportation	Inspection	Delays	Storage	Distance (steps)	Quantity	Total distance (steps)	Time (sec)	Total Time	Notes
1	○	⇨	□	□	▽	1	0	30	30		
2	○	⇨	□	□	▽	1	0	75	75		
3	○	⇨	□	□	▽	5	1	5	5		
4	○	⇨	□	□	▽	1	0	15	15		Depends on worker experience
5	○	⇨	□	□	▽	8	25	200	7	175	
6	○	⇨	□	□	▽	25	0	14	350		Carefully dismantle tank
7	○	⇨	□	□	▽	3	25	75	7	175	Bad posture
8	○	⇨	□	□	▽	1	0	10	10		
9	○	⇨	□	□	▽	1	0	10	10		Spills may occur
10	○	⇨	□	□	▽	1	0	60	60		
11	○	⇨	□	□	▽	1	0	60	60		
12	○	⇨	□	□	▽	10	1	10	10	10	
13	○	⇨	□	□	▽	20	1	20	25	25	
14	○	⇨	□	□	▽	10	5	50	14	70	
15	○	⇨	□	□	▽	1	0	54	54		
16	○	⇨	□	□	▽	1	0	30	30		
17	○	⇨	□	□	▽	1	0	15	15		
18	○	⇨	□	□	▽	1	0	180	180		Unsafe handling
19	○	⇨	□	□	▽	1	0	70	70		
20	○	⇨	□	□	▽	62	1	62	120	120	Unecessary task, can be avoided
21	○	⇨	□	□	▽	20	1	20	25	25	
22	○	⇨	□	□	▽	15	1	15	30	30	
23	○	⇨	□	□	▽	5	1	5	30	30	Already outside
24	○	⇨	□	□	▽	10	1	10	10	10	
25	○	⇨	□	□	▽	1	0	50	50		
26	○	⇨	□	□	▽	1	0	50	50		

FMEA Analysis

FMEA (Failure Modes & Effects Analysis) for Fluid Drainage and Dismantling of fuel tank

Applies to:	Process Step / Input	Potential Failure Modes	Potential Failure Effects	Severity	Potential Causes	Occurrence	Current Controls	Detection	Risk P N	Actions Taken Currently	Actions Recommended	Severity	Occurrence	Risk P N	Diff. on Risk P N																	
F1, F2 & F3	Operator walks back and forth to obtain necessary tools	Inefficient operation	Time is lost on non value added tasks	2	Operator is fatigued	8	Breaks	8	128	None	Movable toolbox Multituse tool that allows worker to work with one tool only	5 5 2	5 5 2	50	- 78																	
F1, F2	Petrol/Diesel is drained using vacuum pump	Petrol/Diesel leakage	Fire	10	Nearby source of ignition	1	Fire extinguisher	2	20	Use fuel spill powder to dry the spill	Floor catchment to contain all spillages	2 1 3	2 1 3	6	- 14																	
F3	Petrol/Diesel is drained manually	Petrol/Diesel leakage	Fire	10	Operator is distracted	2	Training	5	100	Collect Petrol/Diesel onto a closed container automatically	Collect Petrol/Diesel onto a closed container automatically	1 1 2	1 1 2	2	- 98																	
F1	Car is moved from fluid drainage station to the dismantling station	Dismantling station is not available	Time is lost on transportation	2	Dismantling time is not the same as fluid drainage time	8	None	1	16	None	Operate fluid drainage and dismantling at the same station	2 1 1	2 1 1	2	- 14																	
F1, F2 & F3	Fuel Tank Dismantling	Petrol/Diesel spillage	Fire	2	Fuel Tank has residues of Petrol/Diesel	8	None	2	32	Use fuel spill powder to dry the spill	100% Petrol/Diesel drainage from vehicles	1 5 2	1 5 2	10	- 22																	
F1, F2 & F3	Fuel Tank Dismantling	Petrol/Diesel spillage	Fire/ Soil contamination	2	Petrol/Diesel spills when dropping fuel tank	5	None	5	50	Hire experienced dismantlers	Floor catchment to contain all spillages	1 3 3	1 3 3	9	- 41																	
F2 & F3	Petrol/Diesel is transferred to Main Petrol/Diesel storage tank manually	fuel tank not dismantled	fuel tank remains mounted on car	10	fuel tank is too difficult to dismantle	2	No specific instructions to dismantle fuel tank	2	40	Hire experienced dismantlers	Fuel tank design for disassembly (standardize design for all car models)	2 1 1	2 1 1	2	-38																	
F2 & F3	Petrol/Diesel is transferred to Main Petrol/Diesel storage tank manually	Petrol/Diesel spillage	Soil contamination /Water contamination	5	Obstruction on the way	2	Keep pathway clear	10	100	None	Automatically transfer Petrol/Diesel (through overhead/underground pipes) to main storage tank	2 1 5	2 1 5	10	-90																	

Proposed Facility Type (F4) – Flow Process Map

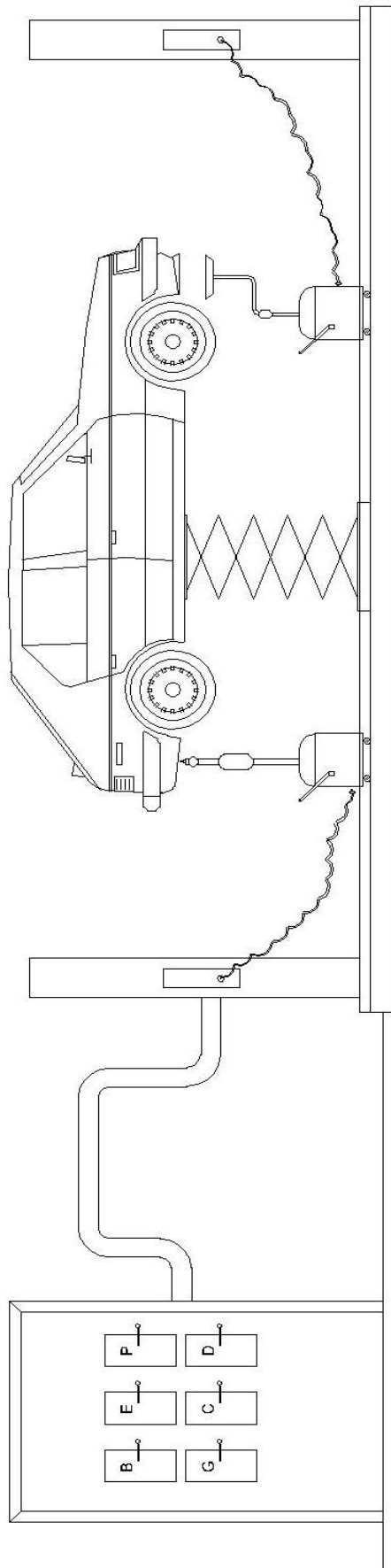


Pugh Matrix

PUGH Matrix for Petrol/ Diesel Drainage

Evaluation Criteria	Facility Type 1				Facility Type 2				Facility Type 3			
	F2	F3	F4		F1	F3	F4		F1	F2	F4	
Reduce petrol/diesel drainage time/vehicle	+	-	++		+	-	++		+	+	++	
Must reduce fuel tank dismantling process time	S	-	S		S	-	S		+	+	+	
Must eliminate spills	-	--	S		S	-	S		+	+	+	
Must drain out maximum amount of petrol/diesel from the vehicle	S	+	S		S	+	S		-	-	-	
Must provide safe working conditions to the worker	-	--	+		+	-	+		+	+	+	
Total (+)	1	1	3		2	1	3		4	4	5	
Total (-)	2	6	0		0	4	0		1	1	1	
Total (s)	2	0	3		3	0	3		0	0	0	

CAD Model of Proposed Solution



Data entered into MS-Excel to perform breakeven analysis (Petrol Vehicles)

Number of Days	Total Fixed Costs(thousands)	Total Variable Costs(Thousands)	Total Sales Revenues(Thousands)
0	771	0	0.00
5	771	10	42.00
10	771	20	84.00
15	771	30	126.00
20	771	40	168.00
25	771	50	210.00
30	771	60	252.00
35	771	70	294.00
40	771	80	336.00
45	771	90	378.00
50	771	100	420.00
55	771	110	462.00
60	771	120	504.00
65	771	130	546.00
70	771	140	588.00
75	771	150	630.00
80	771	160	672.00
85	771	170	714.00
90	771	180	756.00
95	771	190	798.00
100	771	200	840.00
105	771	210	882.00
110	771	220	924.00
115	771	230	966.00
120	771	240	1008.00
125	771	250	1050.00
130	771	260	1092.00
135	771	270	1134.00
140	771	280	1176.00