A STUDY ON TECHNOLOGY CHANGE AND CUSTOMER EXPECTATION IN AUTOMOBILE DIESEL ENGINE SYSTEM

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BONAFIDE CERTIFICATE

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ABSTRACT

Automobile market is considered as one of the emerging market in the present economy. Also at the same time this domain involves frequent technology changes. Within the automobile sector there exists a technology split with respect to the fuel system (Petrol/Gasoline, Diesel) used. On analyzing the technology trends in the past five decades a massive technology growth has been experienced in the diesel engine system compared to gasoline system.

The literature survey clearly shows that there is a huge demand for the diesel cars than the petrol version and henceforth the technology needs improvisation to satisfy the customer expectation and the government legislation norms. The main parameters that guide the technology change for the diesel engine system are fuel efficiency, emission, power, engine noise and vibration, engine maintenance etc. Every time when the technology changes it focus on the above said parameters.

The objective of the study is to analyze the reason behind the technology change and customer expectation in diesel engine system. Using questionnaire the responses from the vehicle users are collected and analyzed using statistical tools to know the expectation out of this technology change. This also gives the information whether these frequent technology change provides any value addition to the customers.

The study reveals that the customers prefer Diesel engines mostly due to fuel efficiency and also they are aware of the emission and environmental pollution caused by diesel engines. Fuel efficiency and emission are the two areas where the customers want to have technology change and improvement.

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V.PRASAD XAVIER

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LIST OF ABBREVIATIONS

ABRV.	EXPANSION
EMS	Engine Management System
DI	Direct Injection
IDI	Indirect Injection
CRDI	Common Rail Diesel Injection
MPFI	Multi Point Fuel Injection
EGR	Exhaust Gas Recirculation
SCR	Selective Catalytic Reduction
FIE	Fuel Injection Equipement
DPF	Diesel Particulate Filter
VM	Vehicle Manufacture

CHAPTER – 1
INTRODUCTION

Automobile market is an emerging market in the current economy. Boston Consulting Group predicts that, by 2014, one-third of world demand will be in the four BRIC markets (Brazil, Russia, India and China). The Automotive industry in India is one of the largest in the world and one of the fastest growing globally. India manufactures over 17.5 million vehicles (including 2 wheeled and 4 wheeled) and exports about 2.33 million every year. India's passenger car and commercial vehicle manufacturing industry is the seventh largest in the world, with an annual production of more than 3.7 million units in 2010 According to the Society of Indian Automobile Manufacturers, annual car sales are projected to increase up to 5 million vehicles by 2015 and more than 9 million by 2020.By 2050, the country is expected to top the world in car volumes with approximately 611 million vehicles on the nation's roads.

On analyzing the trends of investments and levels of technology change in automobile industry ranks top in the past five decades. To sustain in this competitive market all the automobile manufactures are concentrating more on technology. Also top automobile manufactures in the market, into order to maintain their market share, keeps on improvising the technology to provide more comfort, fuel efficiency, power etc to the customers. Literature survey clearly reveals that a massive technology improvement has been experienced in the diesel engine system compared to gasoline system for the past five decades.

1.1 RESEARCH BACKGROUND

On analyzing the past 5 decades there was a tremendous growth in the diesel automobile technology. This growth is achieved by using technology change at different intervals. In automobile engine domain diesel engine contributes a vast majority in terms of growth potential. Also there exists a very frequent technology change in this diesel automobile technology. This change gives a tough challenge to the automobile manufactures. The technology change (improvisation) in the automobile diesel engine system and the customer expectation in automobile diesel engine system were analyzed in this project. Also it is important to analyze the factor that is causing this technology change. This study also analyzes the customer expectation in an automobile diesel engine system.

1.2 IDENTIFIED PROBLEM

Frequent technology change in this automobile sector also leads to problems. For example the automobile models will become obsolete in a short span, also the service stations keeps changing or updating their tools and techniques. Hence frequent change in technology will be a problem for all the relevant stake holders to adapt. In many times the technology change doesn't fulfills the customer expectation and requirements.

This clearly indicates the common man has the potential to state what he needs in a car. This point stresses that a research is needed to identify the reason for the frequent technology change and the customer expectation form the technology change.

1.3 NEED FOR STUDY

Automotive Market is considered as an emerging market in current economy. This Automotive market is facing tough challenge due to frequent technology change. The reason behind the technology change in the automotive diesel engine system needs to be analyzed to find the factor that is causing this technology change.

1.4 OBJECTIVES

The objectives have been grouped into two categories.

Primary Objective

- Technology changes/improvisation in automobile diesel engine system.
- Reason for the technology change in automobile diesel engine system.
- Customer expectation in diesel engine technology

Secondary Objective

- To study about the different types diesel engine systems.
- To study the different cause for technology change.
- To study on the different emission standards for diesel engine.
- To study the technology change due to emission control.

1.5 SCOPE OF THE PROJECT:

The study involves gathering expectations from customers and people who are using or planning to buy a car in near future. The scope of the study is categorized as below.

- The domain under study is restricted to 'Diesel engines' in passenger cars.
- The area of research consists of
    - People who owns a car
    - People who are interested in diesel cars and are about to buy.

1.6 DELIVERABLES

The deliverables of this study are,

- Identify the reason behind the technology change in automobile diesel engine system.
- The customer expectations from the technology change.

CHAPTER – 2
LITERATURE SURVEY

2.1 REVIEW OF LITERATURE

Most analysts expect continued growth in the diesel market. Researchers at J.D. Power and Associates predict that diesel sales will approximately triple in the next 10 years, accounting for more than 10 percent of U.S. vehicle sales by 2015 - up from 3.6 percent in 2005. In this era of sky-high gasoline prices, Americans are increasingly looking to fuel-efficient diesel as a solution to help alleviate their pain at the pump. And because today's diesel vehicles are also clean, quiet and fun-to-drive, many consumers are learning diesel is an environmentally conscious option that does not sacrifice power or performance

In a separate report, *J.D. Power researchers* found that the percentage of new-vehicle shoppers who are considering a hybrid has declined while interest in clean diesel has grown. In 2007, 23 percent of new car shoppers would consider a clean diesel, up from only 12 percent in 2006. On average, car buyers interested in diesel are willing to pay an additional $1,491 for the clean diesel option and expect an average additional fuel economy of 15 mpg.

Andrew Nicol. AECC Technical Seminar on Heavy-Duty Vehicle Emissions (Euro VI):
Euro IV and Euro V exhaust emissions limits have been met by development of engine technologies, to minimize dependence on after treatment. Major FIE suppliers likely to follow trend towards Common Rail FIE for most flexibility over injection timing, rate, pressure and number of injections. Development of systems with pressures up to 2400 bar planned. Exhaust emissions regulations have traditionally been met by modifying and improving the engine technologies, specifically: combustion system, boosting system, fuel injection system, and (where applicable) the EGR system

Business Line, Jul 15, 2001 ; Article by Mr. K. Giriprakash DIESEL car sales in India are expected to grow by a whopping 50 per cent by 2010, keeping pace with a new global trend that is witnessing a huge revival of the segment. A top official of Mico Bosch, an auto component major, told Business Line the current market share of diesel cars is around 31 per cent which is expected to rise to 45 per cent by 2010. "We foresee, with current market trends in India and globally, a diesel share of around 45 per cent in 2010 in the cars and multi-utility vehicle segment," the official said. Europe, which embraced diesel, earlier than other markets, will see its share growing from 46 per cent to 55 per cent by 2010, according to current trends. Three years ago, share of the diesel car market in Europe was a mere 12 - 14 per cent. "We will see a huge demand for diesel cars in India soon," the Tata Motors Vice-President for commercial passenger car business unit, Mr Rajiv Dube, said. He said the demand will be fuelled more by the fact that diesel engines are at least 35 per cent more fuel efficient than gasoline. "Even though diesel carries a price advantage, its engine is more fuel efficient and more environment friendly," Mr Dube said. He said governments in the West are doling out huge incentives to the diesel car segment leading to a major spurt in sales which has been also been helped by the arrival of better performing common rail technology. Keen to take advantage of the expected boom, Mico has already firmed up plans to set up a common rail injection system while India's largest car maker, Maruti Udyog is setting up a Rs 350 crore diesel engine plant in association with Fiat - General Motors Powertrain. The Maruti Udyog Managing Director, Mr Jagdish Khattar, said recently that the diesel cars market would see a substantial increase during the next few years. Mr Khattar said the new plant would produce 100,000 engines every year. "We want to sell diesel cars on its own merit," Mr.Khattar said According to a JD Power report, global diesel light vehicle sales will increase from 12.5 million in 2003 to 27 million by 2015 with India and South Korea being the drivers behind this growth in Asia. A DaimlerChrysler spokesperson said nearly 43 per cent of total CKD sales in India in 2003 were diesel-powered cars. DaimlerChrysler sells E270CDI and C 220CDI Mercedes Benz cars in the country. Ford India's Vice-President for marketing and sales, Mr Vinay Piparsania, said customers prefer diesel run cars for travelling long distances indicating that the price differential between the Global diesel light vehicle sales will increase from 12.5 million in 2003 to 27 million by 2015 with India and South Korea being the drivers in Asia

Honda's next-generation diesel engine By Mike Hanlon: Honda has developed a next-generation diesel engine that reduces exhaust gas emissions to a level equal to a petrol engine and expects to have the engine available in its U.S. market cars within three years. The engine employs an Nox catalytic converter that enables a reduction in NOx emissions sufficient to meet stringent U.S. Environmental Protection Agency (EPA) Tier II Bin 5 emission requirements. Honda has reduced the amount of NOx and soot normally found in engine exhaust, while increasing power output. Along with developing technology for cleaning exhaust gas, Honda plans to address other technical challenges in developing clean diesel engines, such as handling diesel fuels with different cetane numbers and meeting U.S. On-Board Diagnostic System requirements. Petrol engines presently employ three-way catalytic converters that offer NOx reduction rates as high as 99%, but this performance is possible only at the stoichiometric air-fuel ratio. In the oxygen-rich environment of a lean-burn diesel engine, three-way catalytic converters only reduce NOx levels by approximately 10%. Honda's new catalytic converter efficiently reduces NOx in a lean-burn atmosphere, enabling diesel engines to rival petrol engines in cleanliness. The compact system is also easy to install in passenger vehicles.

Article from *Frost & Sullivan Research Service*: Diesel engines are gaining in popularity, penetrating even those vehicle segments that have traditionally been considered gasoline engine strongholds. For instance, the luxury and sports vehicle segments are beginning to favour diesel engines for their improved performance and power density as well as greater refinement in terms of superior noise, vibration and harshness (NVH) characteristics. Market share of diesel engines has been steadily increasing, from a more or less constant 14 per cent between 1987 and 1991 to 33 per cent in 2000 and then to around 45 per cent in 2003, largely due to the introduction of sophisticated technologies such as direct injection (DI), variable geometry turbocharging and common rail direct injection (CRDI). Exhaust gas after-treatment systems such as diesel particulate filters (DPFs) are expected to significantly grow during the study period with penetration rates likely to reach 35 per cent in 2010. Vehicle manufacturers (VMs) are favoring DPFs because of their huge potential with regard to particulate matter and oxides of nitrogen reduction. Governments are also doing their bit to encourage the adoption of DPFs, offering fiscal incentives for vehicles equipped with such solutions. VMs and suppliers are taking full advantage of

these benefits, thereby increasing the penetration rates of DPFs. "Frost & Sullivan estimates that the revenues generated by DPFs will reach €1.47 billion in 2012 with the number of units in the region of 4.2-4.4 million," says the analyst. "The most important contributor to this is expected to be the increased penetration rates of DPFs due to increasingly strict emission norms."

Article from Times of India by Mr. Pankaj Doval, Jan 19, 2011, The growing gap between the pricing of petrol and diesel is likely to give a boost to diesel-powered vehicles as more and more people prefer to cash in on the lower price of the fuel that also fetches more mileage. The gap, now as high as Rs 20, will add to the already-rapid growth of diesel-powered vehicles just as companies are also expected to bring out more vehicles with diesel option. Officials from top car companies like Maruti, Hyundai and Toyota feel that the shift would happen faster if the wide gap continues. "If this substantial price differential continues for long, more and more people will prefer to go for diesel," said Shashank Srivastava, chief general manager (marketing) at Maruti Suzuki. "The refinement in diesel technology and the higher fuel efficiency the engines give are other reasons for their growing popularity."

The share of diesel cars in overall car sales is around 28% currently, and the figure has been climbing up steadily. Srivastava said that diesel used to be about 23% of the overall car market in 2005-06 and the price advantage the fuel offers has been driving demand. Sales of diesel vehicles have experienced a CAGR of 22% between 2005-06 and 2008-09, while for petrol it was 12%, clearly highlighting the shift in preference. Also, while diesel vehicles are priced around a lakh (rupees) higher than comparable petrol model, their higher fuel efficiency means lower running cost-Rs 1.90 per km for diesel to petrol engine's Rs 4 per km. "With this benefit, the higher price of the diesel vehicle can be recovered in about 3-4 years, if the vehicle runs about 37000-38000 kms," Srivastava said. For Maruti, diesel is a big number churner. The share of diesel in the Swift hatchback and Dzire sedan is as high as 67%, while in the Ritz compact, it accounts for about 47%. Arvind Saxena, director (sales and marketing) at Hyundai India, agreed that the growing gap would benefit diesel-powered vehicles. "It is a big motivation to move towards diesel vehicles as their viability gets better. If diesel prices are not de-regulated as is happening in petrol, the incentive will always be there and diesel will be increasingly preferred," he said.

From *dwsAuto analysis by Roshun Povaiah:* The analysis showed that hatchback models with petrol-only options that sell over 5,000 cars a month (Maruti Alto, Hyundai Santro, Maruti Wagon R, Hyundai i10 and Tata Nano), saw a decline in sales by 17.5% in the first five months this year.

"Nearly 70 percent of our sales of the Swift and Ritz are in favor of the diesel variant. This trend will continues especially after the recent hike in petrol prices and Maruti too is focusing on diesel variants for its cars t"

- Mayank Pareek, Managing Executive Officer, Maruti Suzuki India Limited.

Ford also sees a significant shift in buyer preference towards the diesel variant of the Ford Figo. "This year we've seen demand go up to 70 percent in favour of diesel." - Nigel E Wark, executive director, marketing sales and service, Ford India.

The buyer logic is not hard to understand. Present day diesel engines are nearly 20 percent more fuel-efficient than their petrol equivalents, and diesel fuel prices are 68 percent less than petrol. These big cost savings are more than enough to offset the higher price for diesel cars (by about 15-20 percent). The diesel economics is getting more and more attractive for buyers. dwsAuto believes this is the beginning of big, long-term shift in the market. And most carmakers seem to think so too.

2.2 RESEARCH GAP

The studies conducted earlier in this domain concentrated on measuring the customer satisfaction level with a particular brand of a car or the customer awareness on the technologies in the car. The previous studies also focused on maximizing the exports in developing countries as India, with the availability of skilled resources. Also the cost cutting measures to get through the cut throat competition was discussed in some of the researches. These have suggested cutting down some sophisticated features available to bring down their prices. Some studies have also analyzed the feasibility in introducing alternative fuel vehicles to save the environment.

But this study analysis on the Technology change and the reason behind the technology change. It also analysis the customers' expectations from the frequent technology change. This would help the manufacturers clearly identify whether the technology change is really helping the customer or not.

CHAPTER – 3
METHODOLOGY

3.1 TYPE OF PROJECT

This study is Exploratory & Descriptive in nature. The study has been conducted in the form of survey, so that the inputs can be received from the respondents. This study also uses the secondary data's from internet, books and journals to identify the reason behind the technology change in this automobile diesel engines.

3.2 TARGET RESPONDENTS

This study analyses what the customers expect from the technology change in a diesel cars they own or would like to own. So the population is characterized by people, who own cars and people who are interested in cars and would like to own cars. So the target respondents are,

- People who own cars.
- People who are interested in cars and would like to own cars in near future.
- IT professionals working in Diesel engine technology.

3.3 ASSUMPTIONS, CONSTRAINTS AND LIMITATIONS

3.3.1 Assumptions

- The secondary data's for this project is collected from Internet, Book and journals. These data's are assumed to be reliable.
- The respondents have given accurate and correct information without any bias, during the survey.

3.3.2 Constraints

- The Researcher is dependents on the internet data and text books.
- The time period for this study is 3 months.
- The research about the topic is up to the knowledge of the researcher.

3.3.3 Limitations

- The quality of the primary data collected depends on the targeted respondent's reliability in providing the data.
- The primary data sample collection is limited to 150 samples. Hence the outcome cannot be generalized.

3.4 SAMPLING METHODS

The sampling method used in this study is Convenience sampling. Questionnaire is used to collect data's from the target respondents and they are analyzed using the statistical tools.

Convenience sampling

This is a type of non-probability sampling which involves the sample being drawn from that part of the population which is close to hand. That is, a sample population selected because it is readily available and convenient. It may be through meeting the person or including a person in the sample when one meets them or chosen by finding them through technological means such as the internet or through phone. The researcher using such a sample cannot scientifically make generalizations about the total population from this sample because it would not be representative enough.

Research design

A research design is the arrangement of conditions for collections and analysis of data in a manner that aims to combine relevance to the research purpose with economy in procedure. The research design is the conceptual structure within which research is conducted it constitutes the blueprint for the collection, measurement and analysis of data. Descriptive research design is used for this study where the pilot study was conducted among the employees and with that knowledge, questionnaires were given to the respondents.

Research design includes:

- Formulating the objectives of the study.
- Designing the methods of data collection.
- Selecting the sample.
- Collecting the data.
- Processing and analyzing the data.
- Reporting the findings.

Sources of data

The task of data collection begins after a research problem has been defined and research design plan chalked out. The primary data are those, which are collected afresh and for the first time, and thus happen to be original in character. The secondary data are those which have already existing collected data by some other else and which have already been passed through the statistical process.

Primary Data

This study collects the primary data from people who owns or willing to own a car and professionals working on the diesel engine system using questionnaire method. This project uses simple Convenience sampling technique from the respondents. The tools used for data collection is through eQuestionnaire's.

Secondary Data

This study uses secondary data collection from automobile journals and magazine, books, automobile manufacture websites, emission norms & standards.

Sample size

The size refers to the number of items or the units to be selected from the population or the universe to constitute a sample. The sample size must not be too large or too small it should be optimum. The sample size for the study includes 150 respondents.

3.5 DATA PROCESSING

3.5.1 METHOD OF DATA COLLECTION

The method of data collection involved is through primary data collection technique.

3.5.2 TOOL FOR DATA COLLECTION

The tool used for data collection is eQuestionnaire. Prior to use the questionnaire for data collection, it is validated through a pilot study.

3.6 TOOLS FOR ANALYSIS

Following tools are used for analysis.

1. Percentage analysis
2. Straight average method (Rank Analysis)
3. Chi Square test

3.6.1 Percentage Analysis

Percentage analysis refers to a special tool in analysis for making comparison between two or more data and to describe the relative terms, the distribution of two or more series of data.

$$Percentage\ analysis = \frac{Number\ of\ respondents}{Total\ respondents}\ x\ 100$$

3.6.2 Straight average method (Rank Analysis)

This method is used to find the average rank of an option in ranking questions. The rank provided for individual options are averaged for total samples and based on this final averaged rank for all options is obtained.

3.6.3 Chi-Square Test

Chi-Square test is one of the simplest and most widely used nonparametric tests in statistical work. The quality Chi-square describes the magnitude of the discrepancy between theory and observation. A chi-square test allows us to test whether the observed proportions for a categorical variable differ from hypothesized proportions. A chi-square test is used when you want to see if there is a relationship between two categorical variables. Chi-square enables as to explain whether or not two arrributes are associated. In order that we may apply the chi-square test either as a test to judge the significance of association between attributes, it is necessary that the observed as well as theoretical or expected frequencies must be grouped in same way and theoretical distribution must be adjusted to give the same total frequency as we find in the case of observed distribution. For a contingency table that has rows and columns, the chi square test can be thought of as a test of independence. In a test of independence the null and alternative hypotheses are:

Hypothesis Ho: The two categorical variables are independent or not associated.

Alternative Hypothesis Ha: The two categorical variables are related.

Karl Pearson developed a test for testing the significance of discrepancy between the experimental values obtained under some theory or hypothesis.This test is know as **chi-square** test of goodness of fit. Karl Pearson proved that the statistics

$$X^2 = \sum_{i=1}^{n} \frac{(O_i - E_i)^2}{E_i}$$

Where

Oi - Observed Frequency

Ei - Expected Frequency E = R*C/N (R -> Row Total and C -> Column Total)

N - Grand Total

n - number of cells in the table.

Chi-square is used to test whether the difference between observed and expected frequencies are frequent . To find chi-square table value, degree of freedom should should be calculated. Degree of freedom is calculated using the formula.

Degree of freedom = (r-1) (c-1)

Where r = numbers of rows

c = numbers of columns

The table value of this degree of freedom is seen using 5% or 1% of significance. If chi-square table value is greater than the chi-square calculated value, null hypothesis is accepted or null hypothesis is rejected.

Based on this null hypothesis is accepted when Oi < Ei

And Alternate hypothesis is accepted when Oi > Ei

TECHNIQUES USED FOR REPRESENTATION OF DATA

- **Bar charts:**

It is a Clustered column with 3 – D visual affect the bars of same width and only the length varies.

- **Pie – chart graphs:**

Division of the whole or parts of the whole. It can lay out large portion first clockwise position. It is easy to group.

CHAPTER – 4

DATA ANALYSIS AND INTERPRETATION

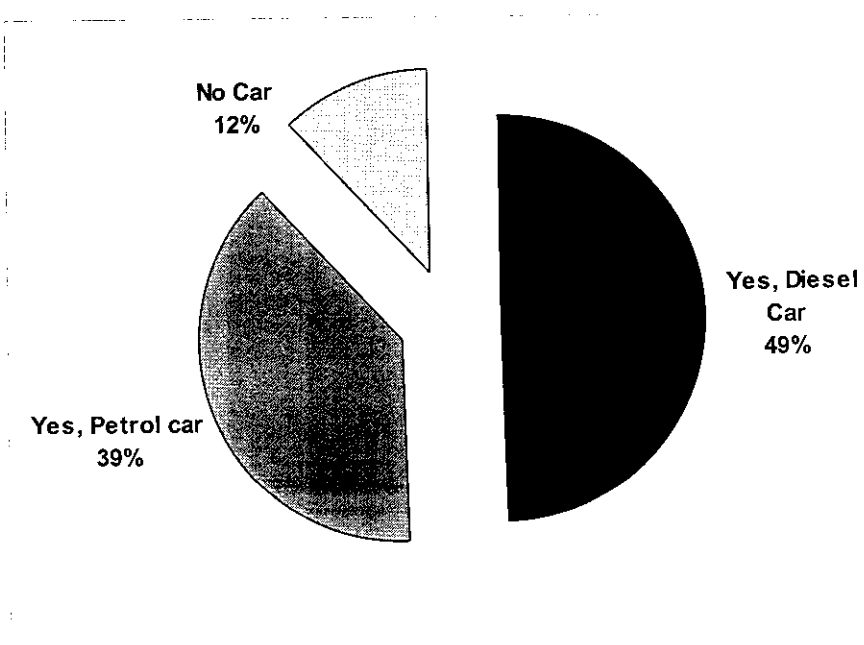
4.1 ANALYSIS USING PERCENTAGE ANALYSIS METHOD

4.1.1 Status of owning Car

Table 4.1.1: Table showing the status of the respondent owing car

S.no	Response	No. of respondents	% of respondents
1	Yes, Diesel Car	74	49
2	Yes, Petrol Car	58	39
3	No Car	18	12
	Total	150	100

Figure 4.1.1: Chart showing the status of the respondents own car



Interpretation:

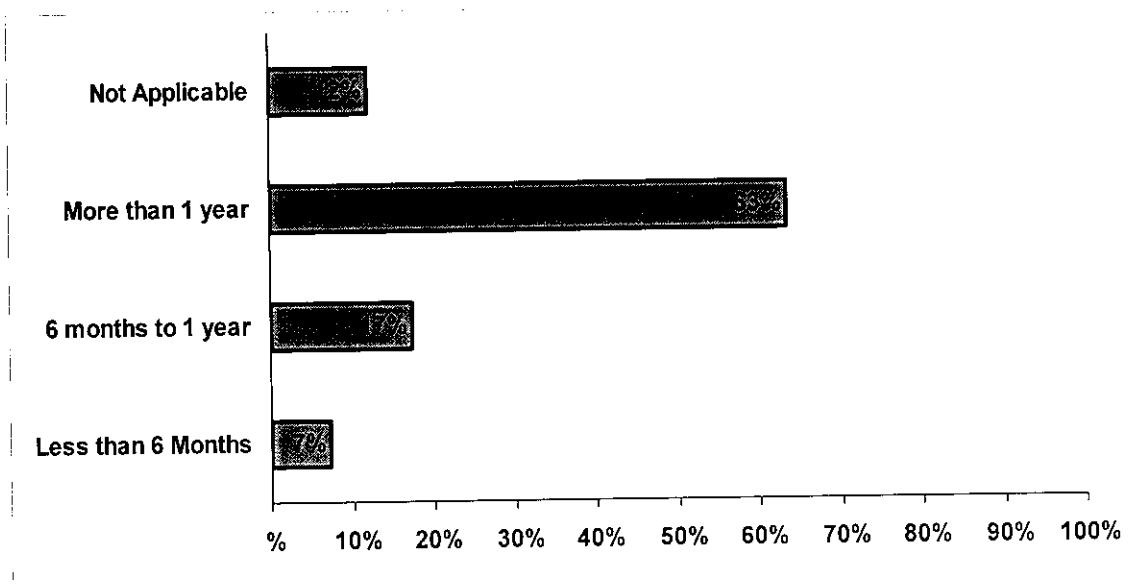
Almost 49% of the respondents own a diesel car and 39% own a petrol car, also 12% of the respondents don't have a car. Hence it interpreted that the number of respondents with diesel car is more than the one with petrol car.

4.1.2 Time of purchase

Table 4.1.2: Table showing the time of purchase of the car

S.no	Response	No. of respondents	% of respondents
1	Less than 6 months	11	7
2	6 months to 1 year	26	17
3	More than 1 year	95	63
4	Not Applicable	18	12
	Total	150	100

Figure 4.1.2: Chart showing the time of purchase of car



Interpretation:

About 7% of the respondents own a car for the last 6 months, 17% within 6 months to 1 year and 63% purchased the car more than a year back.

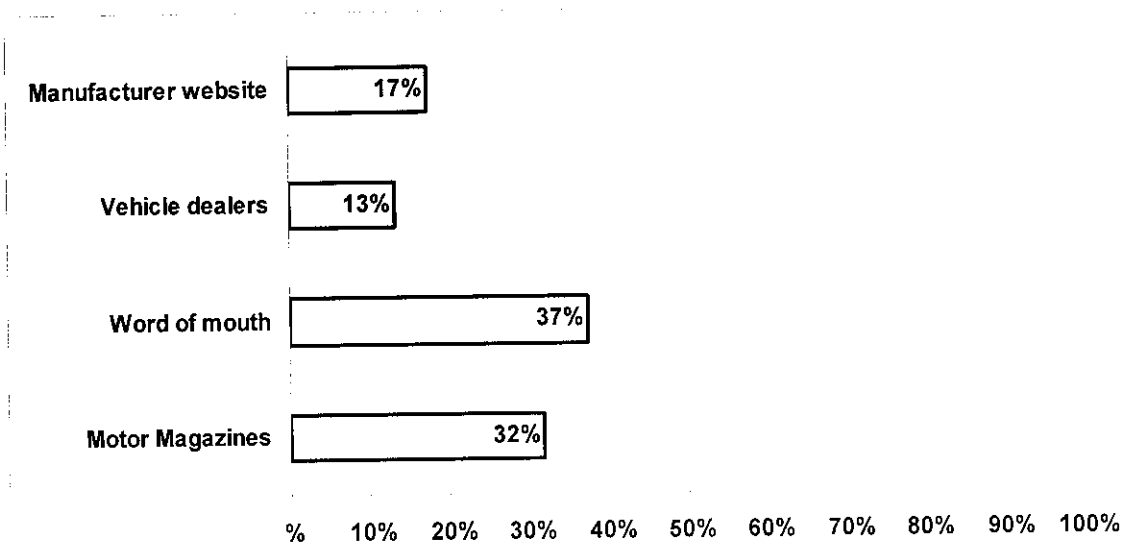
Hence it is interpreted that majority of the respondents owns a car for more than a year.

4.1.3 Source of Information for Car purchase

Table 4.1.3: Table showing the source used by the respondents for car purchase

S.no	Response	No. of respondents	% of respondents
1	Motor Magazine	48	32
2	Word of mouth	56	37
3	Vehicle dealers	20	13
4	Manufacturer website	26	17
	Total	150	100

Figure 4.1.3: Chart showing the source used by the respondents for car purchase



Interpretation:

From the above table it is interpreted that 17% of the respondents refers to manufacturer website, 13% on vehicle dealers, 37% on word of mouth and 32% refers to motor magazines

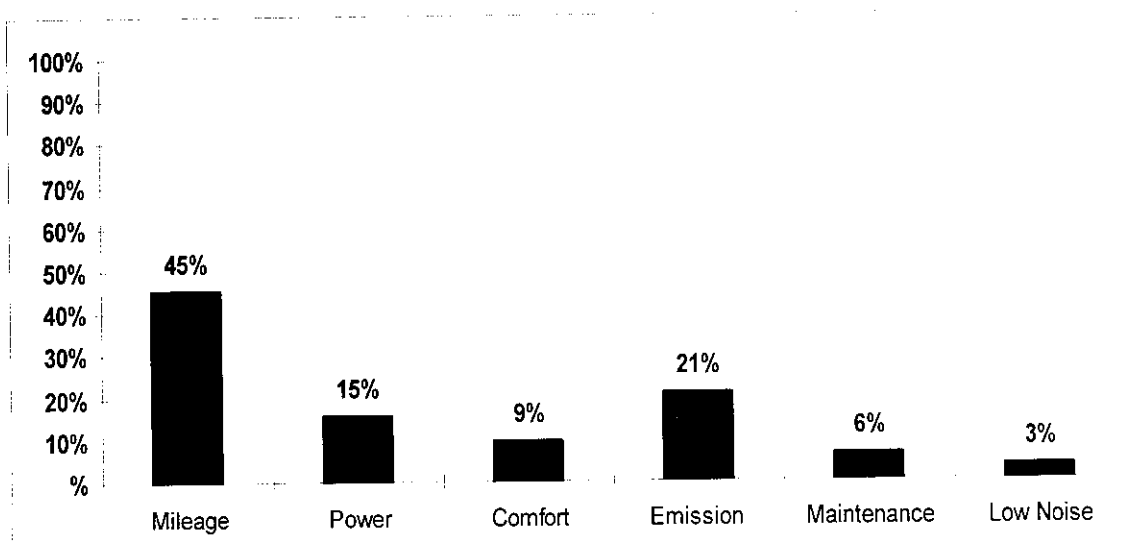
Hence it interpreted that most of the respondents refer the information from the peers regarding the new car purchase.

4.1.4 Top priority parameter during a new Car purchase

Table 4.1.4: Table showing the top priority parameter for the respondents during a new car purchase

S.no	Response	No. of respondents	% of respondents
1	Mileage	68	45
2	Power	23	15
3	Comfort	14	9
4	Emission	31	21
5	Maintenance	9	6
6	Low noise	5	3
	Total	150	100

Figure 4.1.4: Chart showing the top priority parameter for the respondents during a new car purchase



Interpretation:

From the above table it clear that, about 45% of the respondents consider mileage as their top priority and 21% consider emission as their top priority.

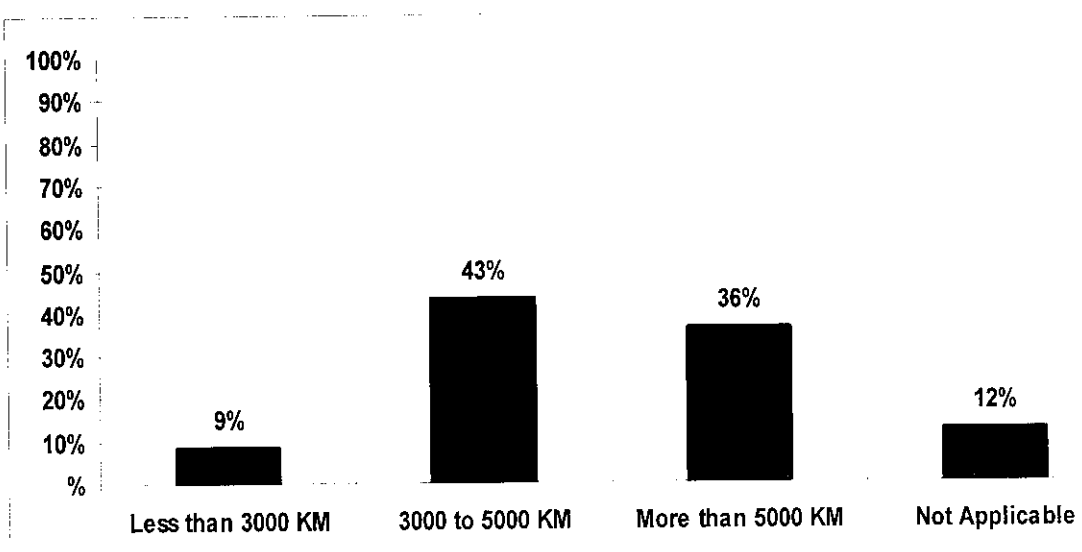
Hence it is interpreted that most of the respondents consider mileage as their top priority.

4.1.5 Average Kilometer driven per Year

Table 4.1.5: Table showing the average kilometer the respondents drive per year.

S. no	Response	No. of respondents	% of respondents
1	Less than 3000 Km	13	9
2	Between 3000 to 5000 Km	65	43
3	More than 5000 Km	54	36
4	Not applicable	18	12
	Total	150	100

Figure 4.1.5: Chart showing the average kilometer the respondents drive per year



Interpretation:

The inference from the above table is, 43% of the respondents drive an average of 3000 to 5000 Km per year and 36% drive more than 5000Km in a year.

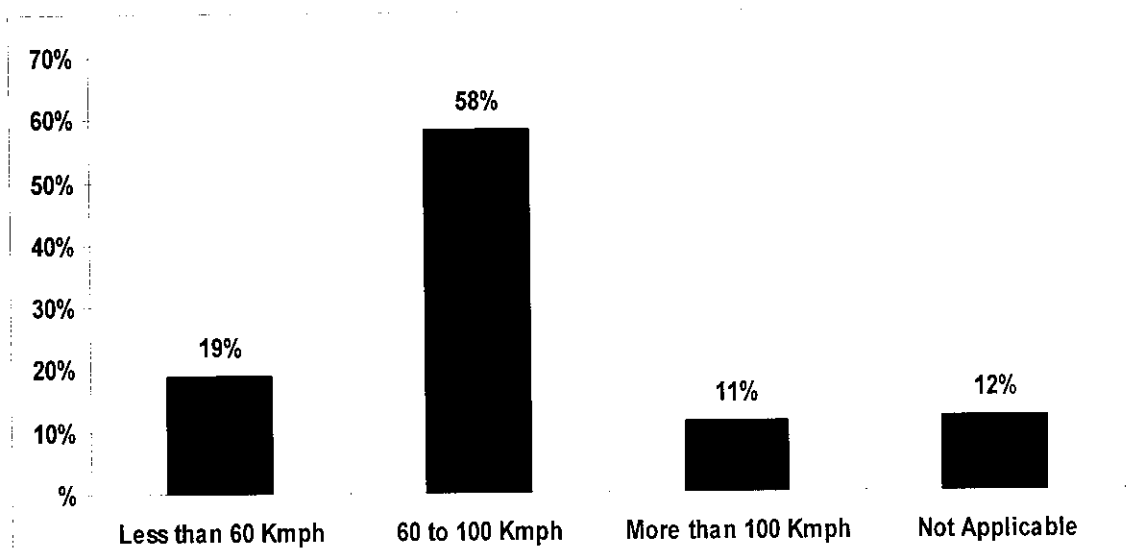
Hence it is interpreted that most of the respondents drive 3000 to 5000 Km per year on an average.

4.1.6 Top speed wish to drive

Table 41.6: Table showing the top speed the respondents wish to drive.

S. no	Response	No. of respondents	% of respondents
1	Less than 60 Kmph	28	19
2	Between 60Kmph to 100Kmph	87	58
3	More than 100 Kmph	17	11
4	Not applicable	18	12
	Total	150	100

Figure 4.1.6: Chart showing the top speed the respondents wish to drive.



Interpretation:

From the above table it is clear that majority of 58% of the respondents wish to drive on a top speed of 60kmph to 100kmph and 19% less than 60Kmph.

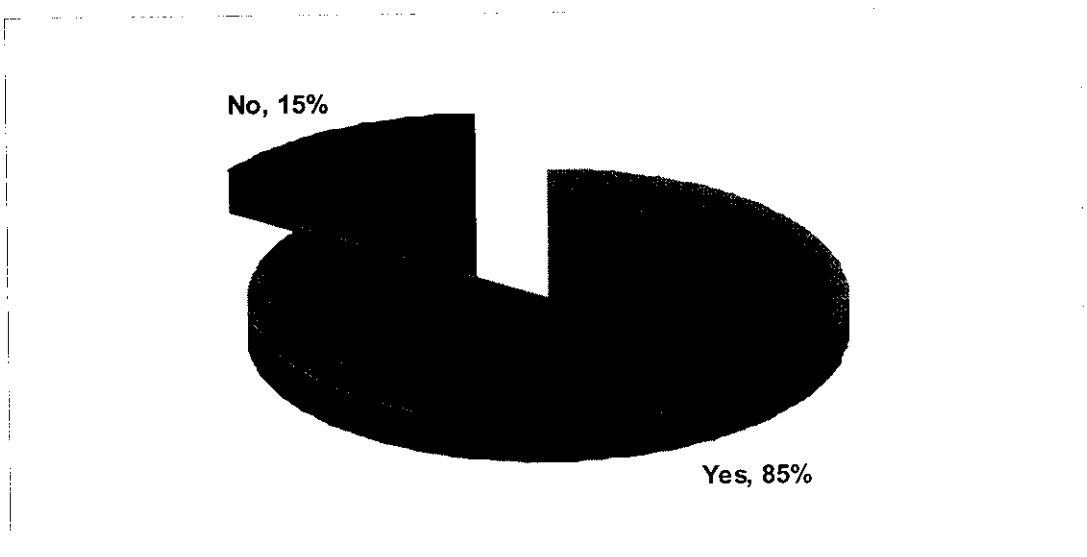
Hence it is interpreted that majority of the respondents wish to drive a top speed of 60kmph to 100 Kmph.

4.1.7 Awareness of emission norms

Table 4.1.7: Table showing the awareness of emission norms among the respondents.

S. no	Response	No. of respondents	% of respondents
1	Yes, aware	127	85
2	No, not aware	23	15
	Total	150	100

Figure 4.1.7: Chart showing the awareness of emission norms among the respondents.



Interpretation:

From the above table it is clear that majority of 85% of the respondents are aware on the emission norms and only 15% of the respondents are not aware of the emission norms.

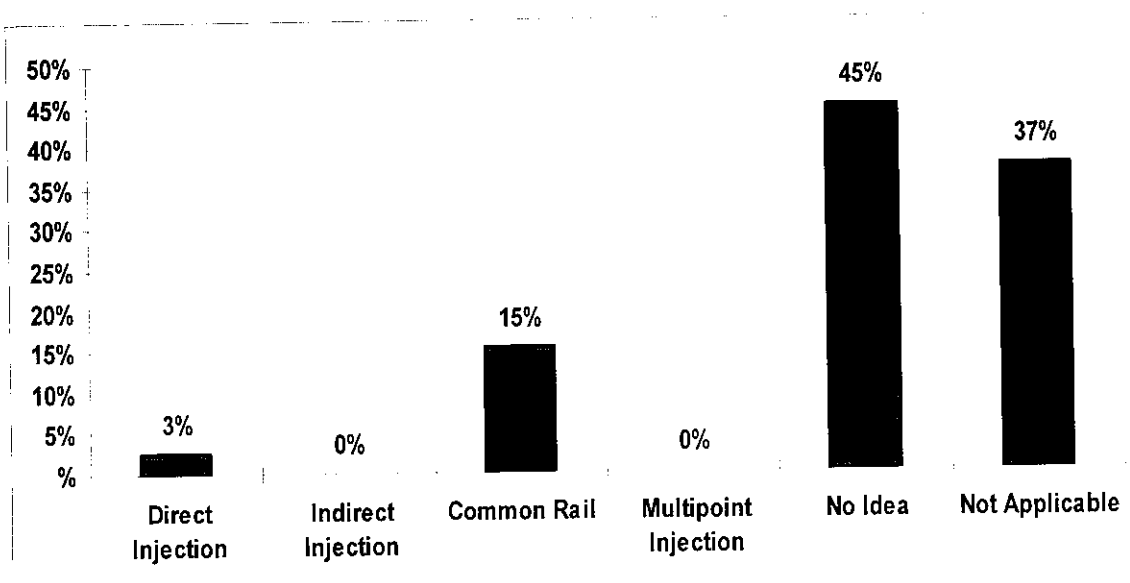
Hence it is interpreted that a majority of the respondents were aware of emission norms.

4.1.8 Type of Diesel engine used in the car

Table 4.1.8: Table showing the type of diesel engine used in the car of the respondents

S. no	Response	No. of respondents	% of respondents
1	Direct Injection system (DI)	4	3
2	Indirect Injection system (IDI)	0	0
3	Common Rail system (CRI)	23	15
4	Multipoint Injection system (MPFI)	0	0
5	No idea	67	45
6	Not applicable	56	37
	Total	150	100

Figure 4.1.8: Chart showing the type of diesel engine used in the car of the respondents



Interpretation:

The above table shows that most of the respondents (45%) have no idea on the injection system used in their car. And 15% of the respondents have CRI system in their car.

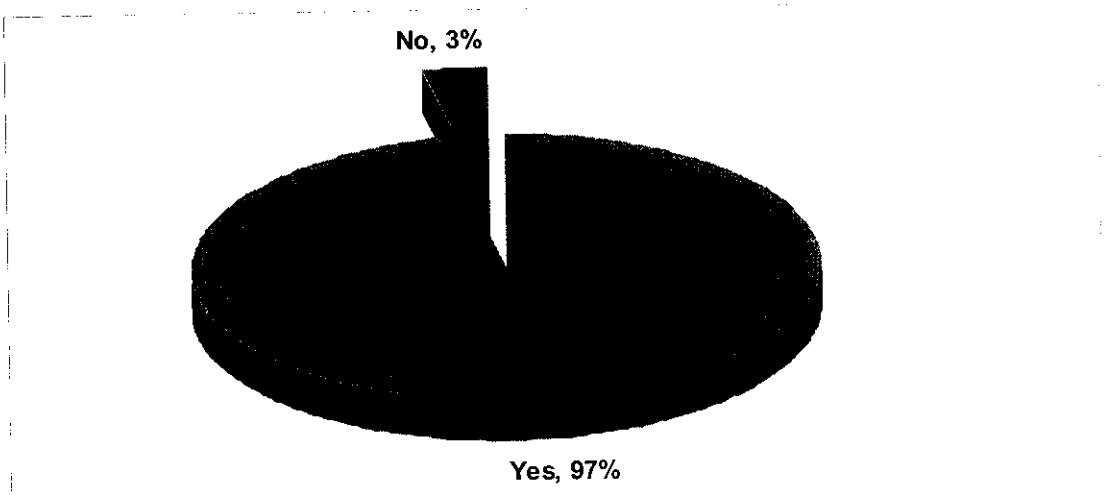
Hence it is interpreted that most of the respondents are not aware of the engine system in their car.

4.1.9 Opinion about the Technology change in Diesel engine system

Table 4.1.9: Table showing the opinion about technology change among the respondents.

S. no	Response	No. of respondents	% of respondents
1	Yes, provides value addition	145	97
2	No, value addition	5	3
	Total	150	100

Figure 4.1.9: Chart showing the opinion about technology change among the respondents.



Interpretation:

The above table shows that majority of 97% of the respondents thinks that the technology change in diesel engines areas provides value addition to them, where as only 3% respondents feels that no value addition out this technology change.

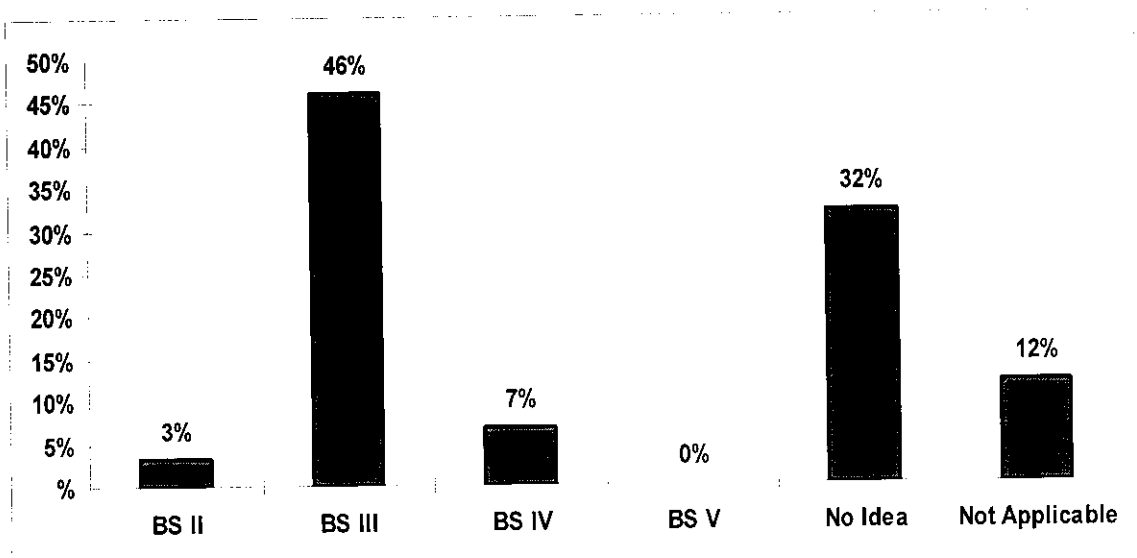
Hence it is interpreted that majority of the respondents thinks the technology change provides value addition to them.

4.1.10 Knowledge of emission standard in the Car

Table 4.1.10: Table showing the knowledge of the emission standard of their car

S. no	Response	No. of respondents	% of respondents
1	Bharat Stage II	5	3
2	Bharat Stage III	69	46
3	Bharat Stage IV	10	7
4	Bharat Stage V	0	0
5	No idea	48	32
6	Not applicable	18	12
	Total	150	100

Figure 4.1.10: Chart showing the knowledge of the emission standard of their car



Interpretation:

The inferences from the above table it that 46% of the respondents are using car with emission norms BSIII complaint. Also 32% of the respondents are not aware of the emission compliance of their car.

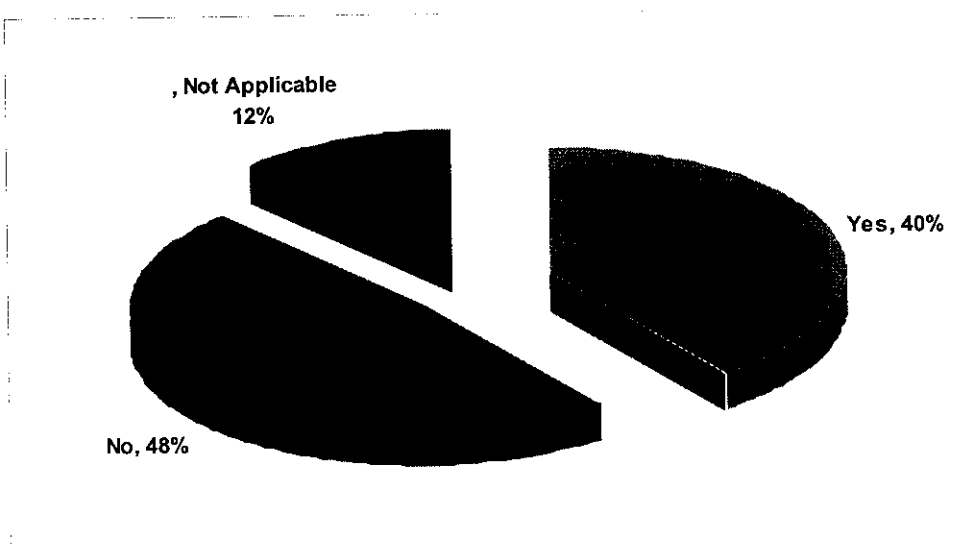
Hence it is interpreted that most of the respondents are using car that is BSIII complaint.

4.1.11 Awareness of exhaust treatment system used in the car

Table 4.1.11: Table showing the awareness among the respondents regarding the exhaust treatment system used in their car.

S. no	Response	No. of respondents	% of respondents
1	Yes, aware	60	40
2	No, not aware	72	48
3	Not applicable	18	12
	Total	150	100

Figure 4.1.11: Chart showing the awareness among the respondents regarding the exhaust treatment system used in their car.



Interpretation:

The above table shows that about 48% of the respondents was not aware of the exhaust treatment system used in their car whereas 40% of the respondents have idea on the exhaust treatment system used in their car.

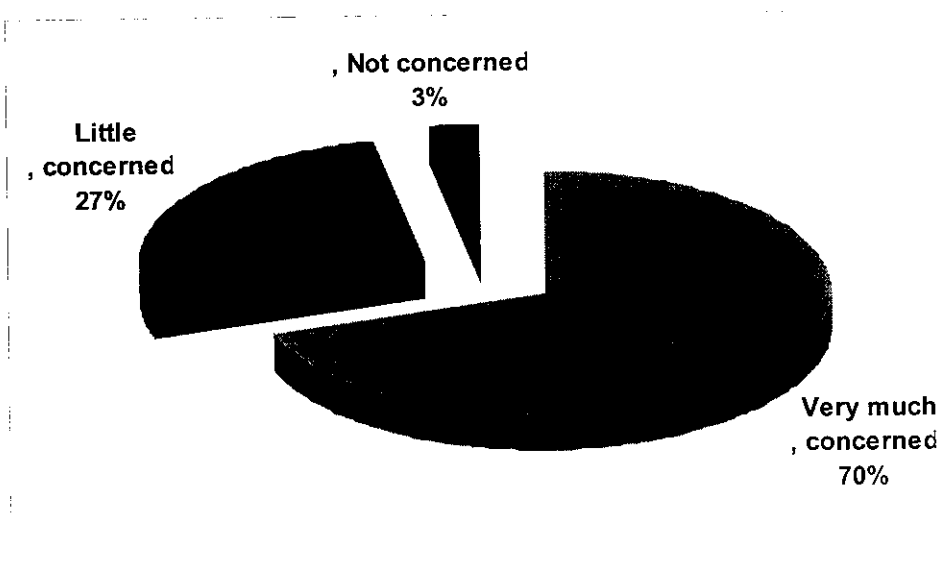
Hence it is interpreted that majority of the respondents are nor aware of the exhaust treatment system used in their car.

4.1.12 Concern about the engine in the car or relay with the vehicle manufacturer

Table 4.1.12: Table showing the importance the respondents gives for the engine system

S. no	Response	No. of respondents	% of respondents
1	Yes, very particular with engine	105	70
2	Yes, less concerned	41	27
3	Not concerned	4	3
	Total	150	100

Figure 4.1.12: Chart showing the importance the respondents gives for the engine system



Interpretation:

From the above table it is clear that about 70% of the respondents were very much concerned with the engine and 27% not so concerned with the engine during the new car purchase.

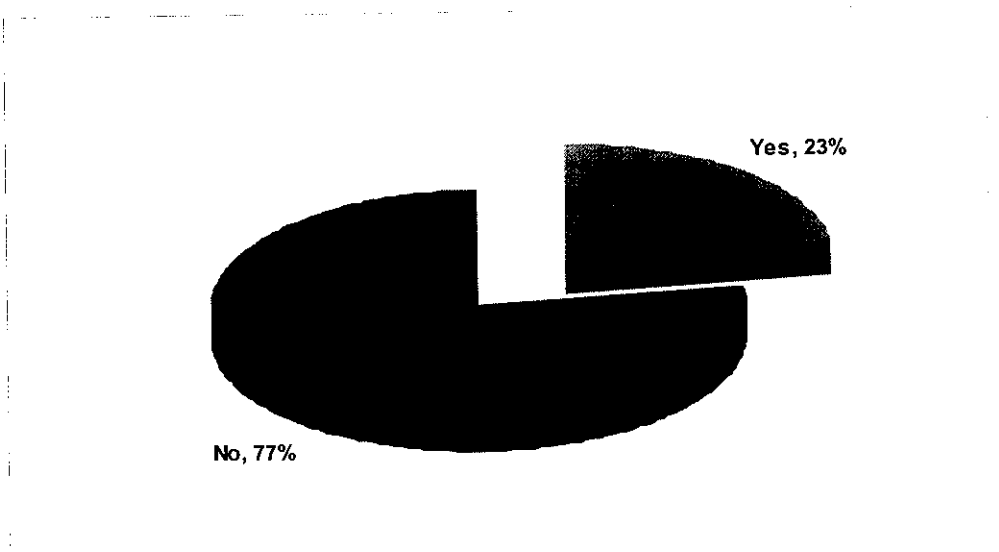
Hence it is interpreted that the majority of the respondents are very much concerned on the engine that the brand of the car.

4.1.13 Willingness to pay more for higher emission norms

Table 4.1.13: Table showing the willingness of the respondents to pay more for higher emission norms

S. no	Response	No. of respondents	% of respondents
1	Yes, I can pay	34	23
2	No, not willing to pay more	116	77
	Total	150	100

Figure 4.1.13: Chart showing the willingness of the respondents to pay more for higher emission norms



Interpretation:

The above table shows that majority of (77%) of the respondents are not willing to pay 5% more price to get a higher emission norms car, and only 23% of the respondents are willing to pay more.

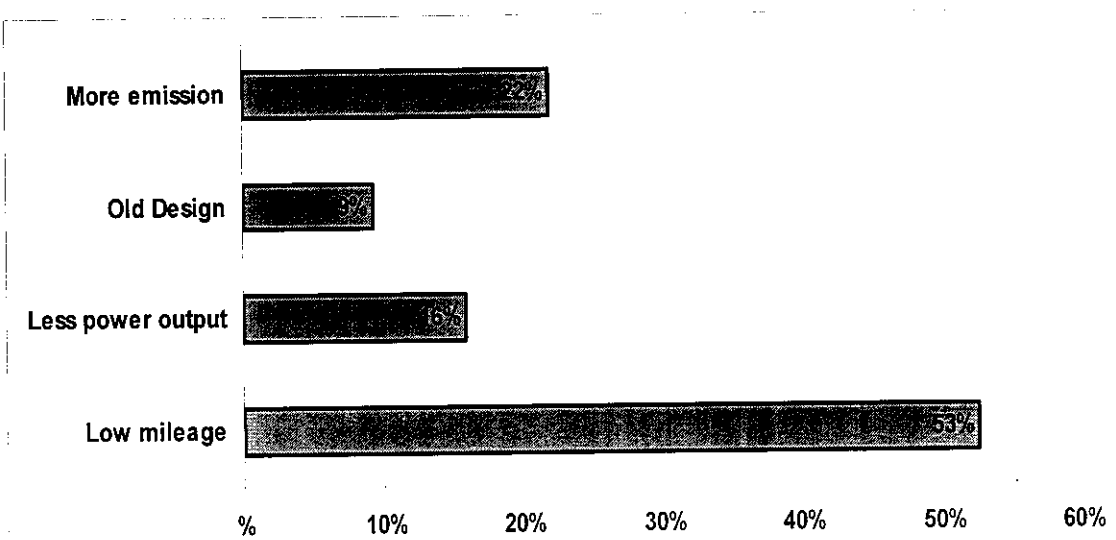
Hence it is interpreted that the majority of the respondents are not willing to pay more to get a higher emission standard.

4.1.14 Reason for a Change/purchase of a new Car

Table 4.1.14: Table showing the respondents view on changing the Car

S. no	Response	No. of respondents	% of respondents
1	Due to less mileage	79	53
2	Due to less power output	24	16
3	Due to old design	14	9
4	Due to more emission	33	22
	Total	150	100

Figure 4.1.14: Chart showing the respondents view on changing the Car



Interpretation:

The above table shows that majority (53%) of the respondents change the car due to low mileage and 22% of the respondents change because of more emission.

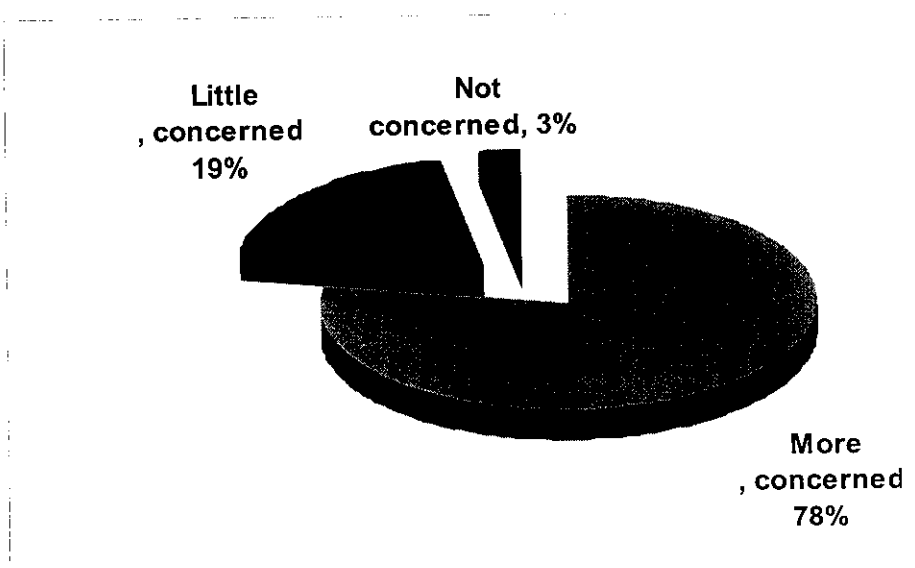
Hence it is interpreted that majority of the respondents change the car due to low mileage.

4.1.15 Concern if the Car produce more emission

Table 4.1.15: Table showing the importance the respondents gives if more emission from their car is noticed

S. no	Response	No. of respondents	% of respondents
1	Yes, more concerned	117	78
2	Yes, less concerned	29	19
3	Not concerned	4	3
	Total	150	100

Figure 4.1.15: Chart showing the importance the respondents gives if more emission from their car is noticed



Interpretation:

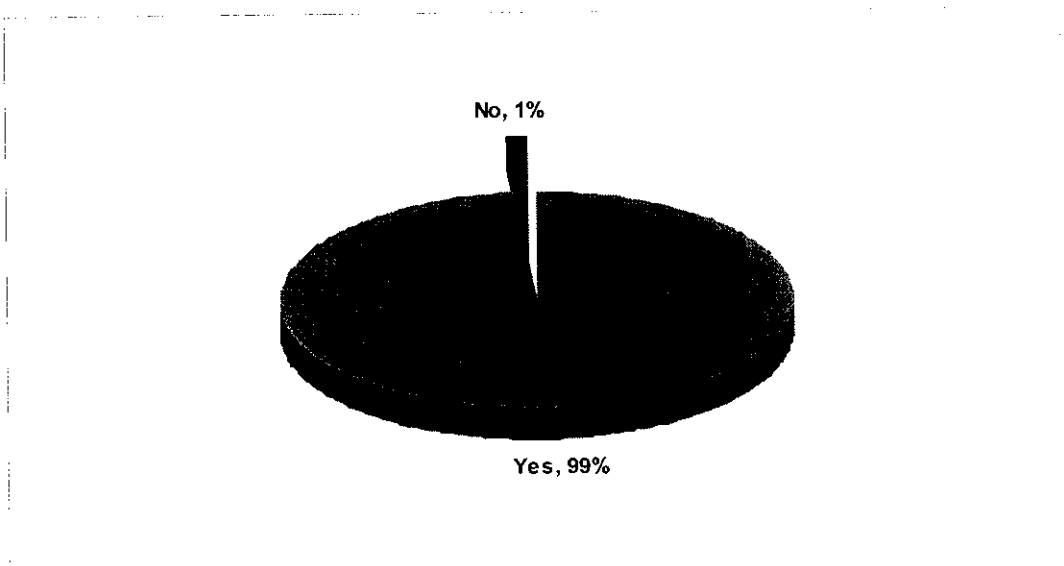
From the above table it is interpreted that the majority (78%) of the respondents gives importance if they notice their car produces more emission.

4.1.16 Opinion regarding Government imposing strict emission norms

Table 4.1.16: Table showing the opinion of the respondents regarding govt. strict emission norms

S. no	Response	No. of respondents	% of respondents
1	Yes, strict emission norms needed	148	99
2	No, not needed	2	1
	Total	150	100

Figure 4.1.16: Chart showing the opinion of the respondents regarding govt. strict emission norms



Interpretation:

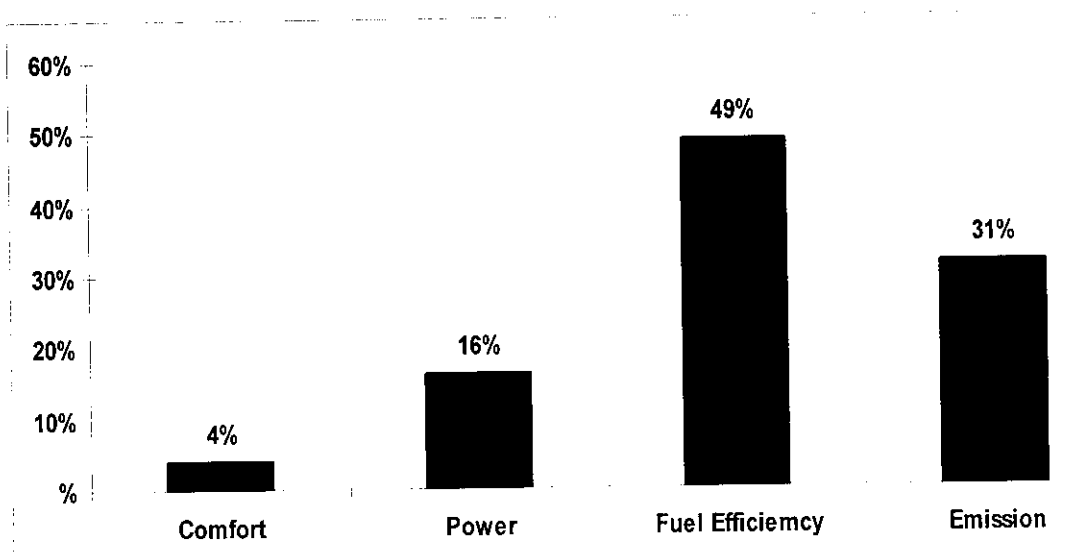
From the above table it is interpreted that, majority of the respondents thinks government can impose strict emission norms.

4.1.17 Opinion on the area of advancement in diesel engine technology

Table 4.1.17: Table showing the respondents opinion on the area of advancement in diesel engine technology

S. no	Response	No. of respondents	% of respondents
1	Comfort Driving	79	53
2	Power	24	16
3	Fuel efficiency	14	9
4	Emission	33	22
	Total	150	100

Figure 4.1.17: Chart showing the respondents opinion on the area of advancement in diesel engine technology



Interpretation:

From the above table it is interpreted that, respondents this technology advancement needed in Fuel efficiency and next is in the area of emission.

4.2 DATA ANALYSIS BY AVERAGE RANKING METHOD

4.2.1 Ranking the preference in a Car

Table 4.2.1 Ranking the preference in a car

S. no	Parameter	Rank Score	Rank
1	Fuel efficiency	1.17	I
2	High power	4.15	IV
3	Less noise	5.42	V
4	Highly reliable engine	3.61	III
5	Low maintenance	2.61	II
6	High speed	5.62	VI
7	High resale value	7.03	VIII
8	Low emission	6.37	VII

Inference:

When the respondents were asked to rank their preferences among the given parameter in a car, the first preference was given to Fuel efficiency. The second and third ranks are bagged by low maintenance and highly reliable engine. Among the given options the last rank goes to resale value.

4.2.2 Ranking the area that needs technology change in diesel engine system

Table 42.2. Ranking the area that needs technology change in diesel engine system

S. no	Parameter	Rank Score	Rank
1	Fuel efficiency	1.51	I
2	High power	5.21	V
3	Less noise	5.60	VI
4	Highly reliable engine	3.29	III
5	Low maintenance	2.52	II
6	High speed	5.15	IV
7	High resale value	6.79	VIII
8	Strict emission norms	5.84	VII

Interpretation:

When the respondents were asked to rank their area that needs technology change among the given parameter in a car, the first preference was given to Fuel efficiency. The second and third ranks are bagged by low maintenance and highly reliable engine. Among the given options the last rank goes to resale value.

4.3 DATA ANALYSIS BY CHI-SQUARE TEST

4.3.1 CHI SQUARE TEST FOR INDEPENDENCE OF ATTRIBUTES

For a contingency table that has rows and columns, the chi square test can be thought of as a test of independence. In a test of independence the null and alternative hypotheses are: Hypothesis H_o : The two categorical variables are independent or not associated. Alternative Hypothesis H_a : The two categorical variables are related. The equation of Chi square = $\Sigma (O_i - E_i)_2$. Here, Oi denotes the frequency of the observed data and E_i is the frequency of the expected values. The general table would look something like the one below:

Table 4.3.a – Chi square general table

	Category I	Category II	Category III	Row Totals
Sample A	a	b	c	a+b+c
Sample B	d	e	f	d+e+f
Sample C	g	h	i	g+h+i
Column Totals	a+d+g	b+e+h	c+f+i	a+b+c+d+e+f+g+h+i=N

Now the expected values for each cell in the table can be calculated by using the row total times the column total divided by the grand total (N). For example, for cell 'a' the expected value E_i would be (a+b+c)(a+d+g)/N.

Once the expected values have been calculated for each cell, the same procedure can be used as before for a simple 2 x 2 table.

Table 4.3.b – Tabulation to calculate Chi square observed value

Observed	Expected	$\lvert O_i - E_i \rvert$	$(O_i - E_i)^2$	$(O_i - E_i)^2 / E_i$

Chi square observed value = $\Sigma (O_i - E_i)_2$.

Based on this null hypothesis is accepted when $O_i < E_i$

And Alternate hypothesis is accepted when $O_i > E_i$

4.3.1 Chi square test for association between the gender and type of car

Null Hypothesis (H_0): There is no association between gender and type of car.

Alternate Hypothesis (H_1): There is an association between gender and type of car.

Level of Significance: 5% level.

Table 4.3.1 – Observed data on new Car Vs diesel Car

		Type of Car		Total
		Diesel	Petrol	
Gender	Male	67	46	113
	Female	7	12	19
Total		74	58	132

Table 4.3.2 - Calculation of observed Chi square value for gender Vs diesel Car

Observed	Expected	$\|O_i - E_i\|$	$(O_i - E_i)^2$	$(O_i - E_i)^2 / E_i$
67	68.3	3.65	13.33	0.21
46	49.65	3.65	13.33	0.27
7	10.65	3.65	13.33	1.25
12	8.34	3.65	13.33	1.6
			Total	3.33

Degrees of Freedom = (no. of rows - 1) (no. of columns - 1) = 1

Observed Chi Square value = 3.33

Expected Chi Square value (referred from Chi Square Table) = 3.84

Interpretation:

Since the Chi Square observed value (3.33) is less than the Chi square expected value (3.84) at 5% level of significance for 1 d.f., we accept the null hypothesis and reject the alternative hypothesis and say that the factors Gender and type of car are not associated.

CHAPTER – 5
CONCLUSIONS

5.1 SUMMARY FINDINGS

The findings are summarized under five major categories as described below.

Respondent's behavior

- Mileage is the one factor that everyone considers as the top factor.
- It's noted that the new car purchase is mostly of diesel engine type.
- The respondents rely on the information from peers during the new car purchase.
- The study clearly indicates that the mileage takes precedence over all the other engine parameters like emission, power, speed, comfort, maintenance etc.
- Almost everyone felt that the technology change in the engine system is providing a value addition to the end user.
- Also form the study it shows the respondents are aware of the emission but not willing to pay more for getting a higher emission standard car.

Respondent's Expectation

- Most of them feel that the government has to impost strict legislation related to emission.
- Fuel efficiency is the area that needs technology advancement.
- Few of the respondents are also thinks emission as a concern, and this needs some technology improvisation.

5.2 CONCLUSIONS

Based on the study the following conclusions are arrived

- There exists two reasons for the frequent technology change in diesel engine system, They are namely
    - The technology change due to customer demand
    - The technology change due to government regulation (forced)
- The top priority parameter in a diesel engine for the customer is fuel efficiency.
- Fuel efficiency and reduced emission are the two parameters that the customer expects for a technology change.
- Customers also prefer government imposing strict emission norms.

5.3 DIRECTIONS FOR FUTURE RESEARCH

Some of the points listed below are some directions for future research in this area.

- The survey is limited to passenger cars. It can be extended to commercial vehicle to get a generalized conclusion across the diesel engine system.
- Future study can focus and correlate the personal factor like Age, Income level, education of the respondents with their preference and expectations.
- Also the adaptation of each OEM's with the customer expectation and technology change can be analyzed.

Appendix – 1

Questionnaire on "**A study on Technology Change and Customer expectation in Automobile Diesel Engine System**"

Dear Respondent,

I, Prasad Xavier working as a Project Manager at Robert Bosch and pursuing MBA in Anna University Chennai (Kumaraguru College of Technology, Coimbatore study center). As a part of MBA curriculum I am doing my Final year project under the topic "A study on Technology Change and Customer expectation in Automobile Diesel Engine System".

You might be aware that, there exists a very frequent technology change in the Automobile diesel engine system. In this study I like to analyze the reason behind the technology change and the customer expectation from the technology change. Henceforth I like to invite you to take up this survey, carried out to study the customer expectation in Automobile Diesel engine system using the Technology change.

Your answers will be of immense help in understanding the reason for the technology change and customer expectation from this technology change. I will assure you that the information provided by you in the questionnaire will be used only for my academic project purpose and will be kept confidential.

Thank you for your co-operation.
Sincerely,
V. Prasad Xavier

Please complete the below details:

Name: _____

Age: _____ Gender: ☐ Male ☐ Female

Educational Qualification: _____

Occupation: _____

Email: _____ Phone #: _____

Monthly Income

☐ 10,000 to 25,000 Rs/- ☐ 25,001 to 50,000 Rs/- ☐ Above 50,000 Rs/-

Please provide a tick mark (✓) for your choice

1. Do you own a Car?

   ☐ Yes, a diesel car ☐ Yes, a petrol car ☐ No

2. When did you purchase the car?

   ☐ < 6 Months ☐ > 6 Months and < 1 year

   ☐ > 1 Year ☐ Not Applicable

3. What source of information do you use when purchasing a new vehicle?

   ☐ Motor Magazines ☐ Word of Mouth

   ☐ Vehicle dealers ☐ Vehicle manufacturer website

4. Among the following parameters which one do you consider as top priority when you plan for a new Car purchase?

   ☐ Mileage ☐ Power ☐ Comfort

   ☐ Emission ☐ Maintenance ☐ Noise

5. On an average, how many Kilometers is your vehicle driven per year?

   ☐ Less than 3000 ☐ Between 3000 KM to 5000 KM

   ☐ Greater than 5000 KM ☐ Not Applicable

6. Which is the top speed you would like to drive?

   ☐ Less than 60 ☐ 60 to 100 Km/Hr

   ☐ More than 100 Km/Hr ☐ Not Applicable

7. Are your aware of emission norms in India and its importance?

   ☐ Yes ☐ No

8. What is the type of Diesel Engine system was used in your Diesel Car?

   ☐ Direct Injection System ☐ Indirect Injection System

   ☐ Common Rail System ☐ Multipoint Injection System

   ☐ No idea ☐ Not Applicable

9. Do you realize the change in the diesel engine technologies really adds any value addition to you/customers?

   ☐ Yes ☐ No

10. Do you know the emission compliance of your Car?

    ☐ Bharat Stage II ☐ Bharat Stage III

    ☐ Bharat Stage IV

    ☐ Bharat Stage V ☐ No Idea ☐ Not Applicable

11. Are you aware of the Exhaust Gas treatment system used in your Car?

    ☐ Yes ☐ No

12. Which of the following parameters of a car you prefer the most? Rank them.

	Most Fuel efficient
	High Power
	Less Noise
	High Reliability Engine
	Low Maintenance
	High Speed
	High Resale Value
	Very low emission

13. Will you give importance to the Engine in the vehicle or simply go with the vehicle manufacture?

    ☐ Very particular with the engine

    ☐ Less concerned

    ☐ Not concerned

14. If given an option to pay 5% more price for a vehicle with higher emission norms do you prefer?

⌐ Yes ⌐ No

15. When will you change/purchase a new vehicle?

⌐ Vehicle giving very poor mileage ⌐ Less power output

⌐ Design looks old ⌐ More exhaust emission

16. In the diesel engine system, which options do you think technology change needs more focus. Rank them

	Fuel efficiency
	High Power output
	Less Noise
	High Reliability Engine
	Low Maintenance
	High Speed
	High Resale Value
	Adhering to strict emission norms

17. Will you give importance if you notice you car producing more emission?

⌐ Yes more concerned ⌐ Little concerned ⌐ Not concerned

18. Do you prefer the government imposing strict emission norms for automobiles?

⌐ Yes ⌐ No

19. If asked for one particular area for technology advancement in an automobile engine system. Which one do you prefer?

⌐ Comfort Driving ⌐ Power ⌐ Fuel efficiency ⌐ Emission

20. If you have any other suggestions, please list it below

_____

_____

Thanks for your valuable feedback!

APPENDIX - 2

CHI-SQUARE PROBABILITIES

The areas given across the top are the areas to the right of the critical value. To look up an area on the left, subtract it from one, and then look it up (ie: 0.05 on the left is 0.95 on the right)

df	0.995	0.990	0.975	0.950	0.900	0.100	0.050	0.025	0.010	0.005
1	—	—	0.001	0.004	0.016	2.706	3.841	5.024	6.635	7.879
2	0.010	0.020	0.051	0.103	0.211	4.605	5.991	7.378	9.210	10.597
3	0.072	0.115	0.216	0.352	0.584	6.251	7.815	9.348	11.345	12.838
4	0.207	0.297	0.484	0.711	1.064	7.779	9.488	11.143	13.277	14.860
5	0.412	0.554	0.831	1.145	1.610	9.236	11.070	12.833	15.086	16.750
6	0.676	0.872	1.237	1.635	2.204	10.645	12.592	14.449	16.812	18.548
7	0.989	1.239	1.690	2.167	2.833	12.017	14.067	16.013	18.475	20.278
8	1.344	1.646	2.180	2.733	3.490	13.362	15.507	17.535	20.090	21.955
9	1.735	2.088	2.700	3.325	4.168	14.684	16.919	19.023	21.666	23.589
10	2.156	2.558	3.247	3.940	4.865	15.987	18.307	20.483	23.209	25.188
11	2.603	3.053	3.816	4.575	5.578	17.275	19.675	21.920	24.725	26.757
12	3.074	3.571	4.404	5.226	6.304	18.549	21.026	23.337	26.217	28.300
13	3.565	4.107	5.009	5.892	7.042	19.812	22.362	24.736	27.688	29.819
14	4.075	4.660	5.629	6.571	7.790	21.064	23.685	26.119	29.141	31.319
15	4.601	5.229	6.262	7.261	8.547	22.307	24.996	27.488	30.578	32.801
16	5.142	5.812	6.908	7.962	9.312	23.542	26.296	28.845	32.000	34.267
17	5.697	6.408	7.564	8.672	10.085	24.769	27.587	30.191	33.409	35.718
18	6.265	7.015	8.231	9.390	10.865	25.989	28.869	31.526	34.805	37.156
19	6.844	7.633	8.907	10.117	11.651	27.204	30.144	32.852	36.191	38.582
20	7.434	8.260	9.591	10.851	12.443	28.412	31.410	34.170	37.566	39.997
21	8.034	8.897	10.283	11.591	13.240	29.615	32.671	35.479	38.932	41.401
22	8.643	9.542	10.982	12.338	14.041	30.813	33.924	36.781	40.289	42.796
23	9.260	10.196	11.689	13.091	14.848	32.007	35.172	38.076	41.638	44.181
24	9.886	10.856	12.401	13.848	15.659	33.196	36.415	39.364	42.980	45.559
25	10.520	11.524	13.120	14.611	16.473	34.382	37.652	40.646	44.314	46.928
26	11.160	12.198	13.844	15.379	17.292	35.563	38.885	41.923	45.642	48.290
27	11.808	12.879	14.573	16.151	18.114	36.741	40.113	43.195	46.963	49.645
28	12.461	13.565	15.308	16.928	18.939	37.916	41.337	44.461	48.278	50.993
29	13.121	14.256	16.047	17.708	19.768	39.087	42.557	45.722	49.588	52.336
30	13.787	14.953	16.791	18.493	20.599	40.256	43.773	46.979	50.892	53.672
40	20.707	22.164	24.433	26.509	29.051	51.805	55.758	59.342	63.691	66.766
50	27.991	29.707	32.357	34.764	37.689	63.167	67.505	71.420	76.154	79.490
60	35.534	37.485	40.482	43.188	46.459	74.397	79.082	83.298	88.379	91.952
70	43.275	45.442	48.758	51.739	55.329	85.527	90.531	95.023	100.425	104.215
80	51.172	53.540	57.153	60.391	64.278	96.578	101.879	106.629	112.329	116.321
90	59.196	61.754	65.647	69.126	73.291	107.565	113.145	118.136	124.116	128.299
100	67.328	70.065	74.222	77.929	82.358	118.498	124.342	129.561	135.807	140.169

APPENDIX – 3

TECHNOLOGY TRENDS IN DIESEL ENGINES

According to the journals published in dieselnet.com which states that due to the technology improvisation for the past five decades the following are the major technology change in the automobile diesel engine technology.

- Direct Injection system (DI)
- Indirect Injection system (IDI)
- Common Rail diesel injection system (CRDI)
- Multi Point fuel injection system (MPFI)
- CRDI with Exhaust Gas treatment system (EGT)

Direct Injection System

In direct injection system the fuel is injected directly into the combustion chamber. Both air and fuel energies contribute to the mixture preparation and consequently to the combustion efficiency. Therefore, significant effort is expended in carefully designing the combustion system and matching it with the fuel spray characteristics to optimize not only engine performance, but also minimize harmful exhaust emissions. Since mixture preparation in this combustion system has more dependency on the kinetic energy of the fuel spray, injection pressure and injector nozzle hole geometry (hole diameter and length) are more important in Direct injection than In Direct injection engines. Direct fuel injection costs more than indirect injection systems: the injectors are exposed to more heat and pressure, so more costly materials and higher-precision electronic management systems are required.

Indirect Injection System

In indirect-injected (IDI) engines, fuel is injected into a pre-chamber connected via a relatively narrow passage to the main combustion chamber. Pre-chamber or IDI engines are sometimes referred to as divided chamber engines. A glow-plug is usually installed in the pre-chamber to assist in cold starting where the fuel spray comes in contact with the red-hot tip of the glow-plug and starts combustion in that limited volume. Gaseous

products flow through the throat connecting the two sections of that divided chamber and continue their oxidation process into the main chamber. Combustion in the pre-chamber is so intense and violent that resulting gases and partially combusted by-products pass through the throat area and develop substantial turbulence in the main chamber. This turbulence is credited with mixing air in the main chamber with the remaining un-burnt fuel as well as the hot by-products from the pre-chamber

Pre-chamber diesel engines have several disadvantages such as lower thermal efficiency, flame impingement on the piston crown while exiting the throat, and in some designs hot gases from the throat may impinge on the valves causing overheating of some critical components and rapid deterioration in lube oil life.

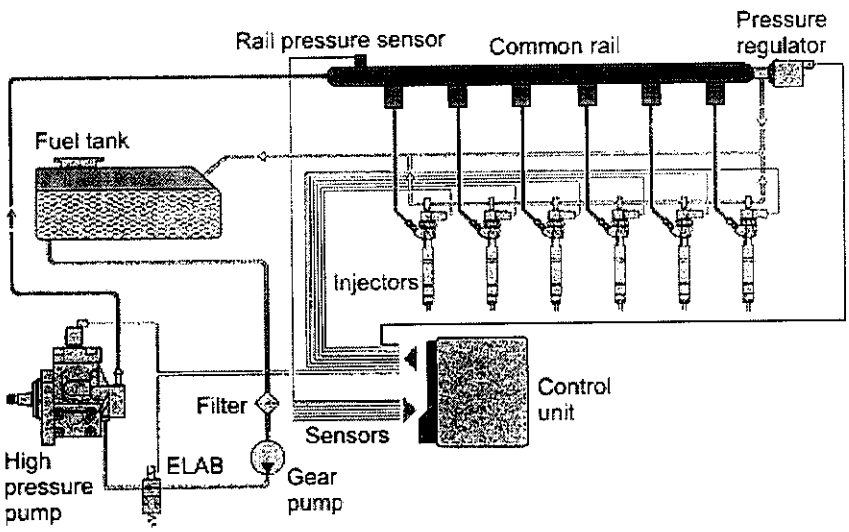
Common Rail diesel injection system (CRDI)

Though this was at the start developed by inventor Robert Huber of Switzerland it was made applicable for wide use in automobiles by Fiat Group which ultimately sold it to German company Robert Bosch. Common rails were first utilized by Denso In 1997 it was used in passenger cars and since then has been wide used in engines developed by Bosch. The compensation of CRDI made its very well loved among urban car buyers in early part of this decade.

In common rail systems, a high pressure pump stores a reservoir of fuel at high pressure — up to and above 2,000 bars (29,000 psi). The term "common rail" refers to the fact that all of the fuel injectors are supplied by a common fuel rail which is nothing more than a pressure accumulator where the fuel is stored at high pressure. This accumulator supplies multiple fuel injectors with high pressure fuel. This simplifies the purpose of the high pressure pump in that it only has to maintain a commanded pressure at a target (either mechanically or electronically controlled). The fuel injectors are typically ECU-controlled. When the fuel injectors are electrically activated, a hydraulic valve (consisting of a nozzle and plunger) is mechanically or hydraulically opened and fuel is sprayed into the cylinders at the desired pressure. Since the fuel pressure energy is stored remotely and the injectors are electrically actuated, the injection pressure at the start and end of injection is very near the pressure in the accumulator (rail), thus producing a square injection rate. If the accumulator, pump and plumbing are sized properly, the injection pressure and rate will be the same for each of the multiple injection events.

The common rail system includes the following components.

- High pressure fuel pump
- Rail for fuel storage and distribution
- Injectors
- Electronic control unit (ECU).

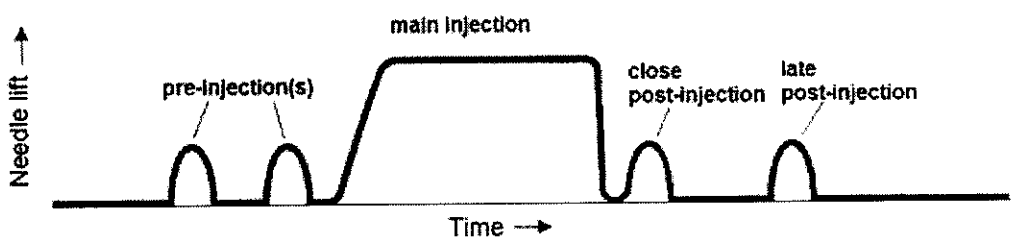


Bosch Common Rail Diesel Fuel Injection System

An electric or camshaft driven low pressure lift pump takes the fuel from the fuel tank, pumps it through a fuel filter and feeds the high pressure pump. A solenoid operated metering valve controls the amount of fuel entering the high pressure pump. The high pressure pump is driven by the engine and delivers fuel at a constant pressure to the rail. A pressure sensor installed in the rail monitors the fuel pressure. The rail serves as a fuel accumulator to maintain a relatively constant pressure at all fueling rates used by the engine. The fuel volume in the rail also dampens pressure oscillations caused by the high-pressure pump and the injection process. From the rail, the fuel is supplied at constant pressure to the injectors via high pressure pipes. The ECU generates current pulses which energize each injector solenoid valve in sequence and define the start and the end of each injection event per engine cycle. The common rail system can generate more than one injection per engine cycle and gives more flexible control of the rate of injection compared to other injection system designs.

Multipoint fuel injection system

While conventional fuel injection systems employ a single injection event for every engine cycle, newer systems can use multiple injection events. The below figure defines some of the common terms used to describe multiple injection events. The main injection event provides the bulk of the fuel for the engine cycle. One or more injections before the main injection, pre-injections, provide a small amount of fuel before the main injection event. Pre-injections can also be referred to as pilot injection. Some refer to a pre-injection that occurs a relatively long time before the main injection as a pilot and one that occurs a relatively short time before the main injection as a pre-injection. Injections after the main injections, post-injections, can occur immediately after the main injection (close post-injection) or a relatively long time after the main injection (late post-injection). Post-injections are sometimes called after-injections. While there is considerable variation in terminology, a close post-injection will be referred to as a post-injection and a late post-injection as an after-injection.



[Source : http://www.dieselnet.com/tech/diesel_fi.html]

The term split injection is occasionally used to refer to multiple injection strategies where a main injection is split into two smaller injections of approximately equal size or into a smaller pre-injection followed by a main injection.

Unintended post-injections can occur in some fuel injection systems when the nozzle momentarily re-opens after closing. These are sometimes referred to as secondary injections.

CRDI with Exhaust Gas Treatment (EGT)

The original purpose of an exhaust system was to safely route exhaust gases from the engine so they can be exhausted into the environment, while also providing attenuation of combustion noise. Exhaust gas, however, contains components that are harmful to human health and/or the environment. As a consequence, emission levels of these exhaust gas components became regulated. Since regulated emission levels are often much lower than that which can be achieved through in-cylinder control measures, the exhaust gas must be treated after it leaves the engine. Thus, while exhaust systems continue to serve their original functions, they have evolved into one of the critical elements used for pollution control and abatement in modern engines.

Diesel Particulate Filter (DPF)

Diesel particulate filters (DPF) are devices that physically capture diesel particulates to prevent their release to the atmosphere. Diesel particulate filter materials have been developed that show impressive filtration efficiencies, in excess of 90%, as well as good mechanical and thermal durability. Diesel particulate filters have become the most effective technology for the control of diesel particulate emissions—including particle mass and numbers—with high efficiencies.

Due to the particle deposition mechanisms in these devices, filters are most effective in controlling the solid fraction of diesel particulates, including elemental carbon (soot) and the related black smoke emission.

Exhaust Gas Re-circulation (EGR)

When air is compressed inside the cylinder of a diesel engine, the temperature of the air is increased enough to ignite diesel fuel after it is injected into the cylinder. When the diesel fuel ignites, the temperature of the air increases to more than 1500° F and the air expands, pushing the piston down and rotating the crankshaft

But, when peak temperatures are high enough for long enough periods of time, the nitrogen and oxygen in the air combine to form new compounds, primarily NO and NO2.

These are normally referred to collectively as "NOx".

NOx can be reduced by lowering cylinder temperatures. This is done by re-circulating some exhaust gas (Exhaust Gas Recirculation) into the cylinder. EGR works by re-circulating a portion of an engine's exhaust gas back to the engine cylinders. Hence in a diesel engine, the exhaust gas replaces some of the excess oxygen in the pre-combustion mixture. Because NOx forms primarily when a mixture of nitrogen and oxygen is subjected to high temperature, the lower combustion chamber temperatures caused by EGR reduces the amount of NOx the combustion generates.

Selective Catalytic reduction (SCR)

Selective catalytic reduction is a means of converting nitrogen oxides, also referred to as NOx with the aid of a catalyst into diatomic nitrogen, N2, and water, H2O. A gaseous reductant, typically anhydrous ammonia, aqueous ammonia or urea, is added to a stream of flue or exhaust gas and is absorbed onto a catalyst. Carbon dioxide, CO2 is a reaction product when urea is used as the reductant.

The NO_x reduction reaction takes place as the gases pass through the catalyst chamber. Before entering the catalyst chamber the ammonia, or other reductant (such as urea), is injected and mixed with the gases. SCR remains the only proven catalyst technology capable of reducing diesel NO_x emissions to levels required by a number of future emission standards. Urea-SCR has been selected by a number of manufacturers as the technology of choice for meeting the Euro V (2008) and the JP 2005 NO_x limits—both equal to 2 g/kWh—for heavy-duty truck and bus engines.

Emissions in Diesel Engine

Unlike spark-ignited engines where the combustible mixture is predominantly homogeneous, diesel combustion is heterogeneous in nature. Diesel fuel is injected into a cylinder filled with high temperature compressed air. Emissions formed as a result of burning this heterogenous air/fuel mixture depend on the prevailing conditions not only during combustion, but also during the expansion and especially prior to the exhaust valve opening. Mixture preparation during the ignition delay, fuel ignition quality, residence time at different combustion temperatures, expansion duration, and general engine design features play a very important role in emission formation. In essence, the concentration of

the different emission species in the exhaust is the result of their formation, and their reduction in the exhaust system. Incomplete combustion products formed in the early stages of combustion may be oxidized later during the expansion stroke. Mixing of unburned hydrocarbons with oxidizing gases, high combustion chamber temperature, and adequate residence time for the oxidation process permit more complete combustion. In most cases, once nitric oxide (NO) is formed it is not decomposed, but may increase in concentration during the rest of the combustion process if the temperature remains high *[Henein 1972]*.

Emissions Standards

Emission standards are requirements that set specific limits to the amount of pollutants that can be released into the environment. Many emissions standards focus on regulating pollutants released by automobiles (motor cars) and other powered vehicles but they can also regulate emissions from industry, power plants, small equipment such as lawn mowers and diesel generators. Frequent policy alternatives to emissions standards are technology standards (which mandate Standards generally regulate the emissions of nitrogen oxides (NOx), sulfur oxides, particulate matter (PM) or soot, carbon monoxide (CO), or volatile hydrocarbons (see carbon dioxide equivalent).

Emission standards in India

Bharat Stage emissions standards are emissions standards instituted by the Government of the Republic of India (Bharat) that regulate the output of air pollutants (such as nitrogen oxides (NOx), carbon monoxide (CO), hydrocarbons (HC), particulate matter (PM), soot, and, where applicable, sulfur oxides (SOx)) by internal combustion engine powered equipment, including motor vehicles.

Emission Standards for Diesel Truck and Bus Engines, g/kWh

Year	Indian	European	CO	HC	NOx	PM
2000	India2000	Euro I	4.5	1.1	8	0.36
2001-2005	BS II	Euro II	4	1.1	7	0.15
2006-2010	BS III	Euro III	2.1	0.66	5	0.1
From 2011	BS IV	Euro IV	1.5	0.46	3.5	0.02
		Euro V	1.5	0.46	2	0.02
		Euro VI	1.5	0.13	0.4	0.01

Emission Standards for Light-Duty Vehicles, g/km

Year	Indian	European	CO	HC+NOx	NOx	PM
2000	India2000	Euro 1	2.72-6.90	0.97-1.70	-	0.14-0.25
2001-2005	BS II	Euro 2	1.0-1.5	0.7-1.2	-	0.08-0.17
2006-2010	BS III	Euro 3	0.64	0.56	0.5	0.05
			0.8	0.72	0.65	0.07
			0.95	0.86	0.78	0.1
From 2010	BS IV	Euro 4	0.5	0.3	0.25	0.025
			0.63	0.39	0.33	0.04
			0.74	0.46	0.39	0.06
		Euro 5	0.5	0.23	0.18	0.005
			0.63	0.295	0.235	0.005
			0.74	0.35	0.28	0.005
		Euro 6	0.5	0.17	0.08	0.0025
			0.63	0.195	0.105	0.005
			0.74	0.215	0.125	0.005

Technology Change in Diesel engine system

On analyzing the transition of the diesel engine technology is mainly due to the following reasons like:

- More driving comfort
- Fuel efficiency.
- More power demand
- Strict emission norms

Hence in order to meet the above demand the diesel engine technology experiences a frequent technology. Also the strict emission norms imposed by the government plays a major role in technology advancement. This is because the current technology wont supports better emission norms.

The demand on driving comfort, fuel efficiency etc will induce a technology change due to customer. The legal norms like compliance to certain emission norms will also force for a technology change.

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