DEVELOPMENT AND IMPACT OF FUEL ECONOMY STANDARDS AND LABELS FOR HEAVY DUTY VEHICLES IN IRAN

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ABSTRACT

Nowadays, motor-vehicles are one the largest consumer of fossil fuels in the world. The transportation sector has the second largest contribution in oil production consumption in Iran. At this time more than 22% of oil productions are consumed by heavy motor-vehicles in transportation sector in Iran. Fuel saving initiatives such as the fuel economy standards and labels program for motor-vehicles in transportation section has been applied as purpose of decreasing the fuel consumption in many developed countries around the world. Many researched have been done on energy efficiency standards but there are few studies on economic analysis of potential efficiency improvement.

In this study represents the fuel economy standards and labels programs for heavy motor-vehicles. The study found the savings has exceeded the investment cost and the program has reduced emissions caused by burning fossil fuel. The purpose of the energy labels is to provide the consumers a guideline to purchasing the most efficient motor-vehicles in market. This research has also investigated the influence of implementing the fuel economy standards and labels program on the fuel savings, economic savings and in addition the influence on the environment.

Consider to the increasing of the quantity of motor vehicles in the country, many advantages will come for the society as well as the environment by using the fuel economy standards and labels program. It is predicted that by implementing this program approximately 9.3 billion liters of fuel will be saved from 2013 to 2018 also the calculated savings is about 43,802 billion in bill. The emission of carbon dioxide will decrease with the amount of around 19 million tons. Therefore, efficiency improvement of heavy motor-vehicles will give a significant impact in the future of fuel consumption in Iran. Furthermore, it has been found that implementing fuel economy standards and labels for heavy motor-vehicles causes to decrease the green house gas emissions.

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LIST OF SYMBOLS AND ABBREVIATIONS

AFI_i	Annual fuel economy ratings improvement in year i(%)
AS_I	Applicable stock in year i
ANS_i	Annualized net savings in year i
AS_{i-1}	Applicable stock in year i-1
BFC_s	Baseline fuel consumption (standard) (liters/year)
BFC_l	Baseline fuel consumption (label) (liters/year)
BFC_{YSC}	Baseline fuel consumption in the year of survey (liters/year)
BS_i	Bill savings in year i (Rials)
CRF	Capital recovery factor
d	Interest rate per year(%)
Em_p	Emission type p for a unit liter (kg/lit)
FC_i	Fuel consumption in year i (liters)
FER_i	Fuel economy rating in year i
FER_{i-1}	Fuel economy rating in year i-1
FER_{STD}	Fuel economy rating in year standards enacted
FER_{Ysc}	Fuel economy rating in year survey is conducted
FER	Fuel economy rating
FS_i	Fuel savings in year i (liters)
IC	Incremental cost of motor vehicle (Rials)
IIC_s	Initial incremental cost fuel efficient motor vehicle (Rials)
L	Lifespan of motor vehicle (years)
LCC	Life cycle cost (Rials)
FCl_l	Label fuel consumption (liters/year)
MC	Annual maintenance cost (Rials)

N	Lifetime (years)
Nv_i	Number of motor vehicles in year i
Nv_{i-1}	Number of vehicles in year i-1
Nv_{i-L}	Number of vehicles in year i-L
η_s	Percentage fuel economy standards improvement of motor vehicle(%)
OC	Annual operating cost (Rials)
PC	Investment costs (Rials)
$PV(ANS_i)$	Present value of annualized net savings in year i (Rials)
PWF	Present worth factor
PF	Fuel Price (Rials)
PC	Investment cost (Rials)
r	discount rate(%)
SFC_{MV}	Standards fuel consumption of motor vehicles (liters/year)
Sh_i	Shipment in year i
SF_i	Scaling factor in year i
SSF_i	Shipment survival factor in year i
TI_S	Total fuel economy improvement(%)
UFS_s	Initial unit fuel savings (liters/year)
UFC_i	Unit fuel savings in year i (liters/year)
Ym	Annual mileage of motor vehicle (km)
Yse_i	Year of standards enacted of motor vehicle
Y_{SC}	Year survey conducted
Ysh_i	Year i of shipment of motor vehicle
Ydr	Year of discount rate base
%STD	Percentage Standards Improvement(%)

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CHAPTER 1
INTRODUCTION

Nowadays with growing the industry it is required to use the transportation sector. Actually the transportation sector has an important and great role in each country especially for developing countries. The transport system can be divided to the two main types. First the kind of cars which are used for carry the passengers and the other one are heavy duty vehicles that except transferring passengers, are used for different goods and various loads. The heavy duty vehicles consume the diesel and gasoline. The increase of using vehicles is unavoidable in any developing country. The growth of transportation system and increment using vehicles with increasing per capita income causes more usage of depleting fuel which has negative impact and effect on the environment. However, patterns of excessive production of greenhouse gases have been numerously studied, but these activities do not play any role in the production of millions of tons of greenhouse gases per year. Therefore, restrictions and guidelines should be put to community resources for preserving non-renewable energy for our future generations. In order to control the huge use of fossil fuel and to reduce the emissions, many methods and solutions have been suggested by researchers and scientists; one of these suggestions is the optimizing of energy consumption (Saidur, Masjuki et al. 2005; Mazandarani, Mahlia et al. 2010; Saidur, Atabani et al. 2011). The other important way is to use renewable energy sources (Fadai 2007; Mohammadnejad, Ghazvini et al. 2011). The implementation of energy policy is an appropriate and effective strategy to provide guidance that helps Iran to reduce overall greenhouse gas emissions.

Generally, fuel economy standards and labels have become a common policy in many countries and regions around the world. Fuel economy can be defined as measured average mileage which is traveled by vehicle per consumption of a gallon of gasoline (or equivalent in another fuel) in accordance with the testing and evaluation protocol. The fuel economy standard has been determined as minimum level of fuel economy that motor vehicles must reach before it is can be legally sold. By implementing the fuel economy standard program, motor vehicles with high fuel consumption will be removed from the market and as a result, it will help the vehicle Iran to reduce overall greenhouse gas emissions and improve competitiveness of motor vehicles in the international arena.

Meanwhile, (Mahlia, Masjuki et al. 2002) defines an energy label which is voluntary or mandatory, that is attached to production or their packaging contains data and information regarding energy consumption or energy efficiency. This label is a tool to impact on vehicle manufacturers to take care about the fuel efficiency and it also enables customers to compare fuel economy vehicles on the market. Fuel economy politics, have become a major public program for developed countries. The countries which use the fuel economy standards program for motor vehicles are trying to enact the laws cause even higher fuel efficiency for motor vehicles; so there are reasons behind this policy that our country should be aware of them. The known advantages behind this policy are: causing the highly competitive industrial, energy security and the environment impact. This effort leads to conserve non-renewable energy resources as well as our environment. In addition, it is the responsibility towards future generations.

1.1 Background

There are many heavy duty vehicles in Iran that consume gasoline which comes from oils resources that are depleting and the burning of them causes the GHG emissions. These emissions have inversed effects on the environment and the health of social. In the following sections the situation of Iran for utilizing the heavy duty vehicles and the Iranian policies about energy are presented.

1.1.1 Heavy duty fleet in Iran

The final consumption of oil products in 2008 is shown and the Figure 1.1 shows the percentage of energy used in transport sector due to the fuel types. As can be seen in this figure around 38.37% of the oil productions are being used for heavy duty vehicles in Iran. The diesel is used by the buses, mini-buses, lorries specially the fleet of transport in the roads for goods and etc. These data are collected from the transport data book which is published by the optimization fuel consumption organization (Parsafar, Mirzaee et al. 2010).

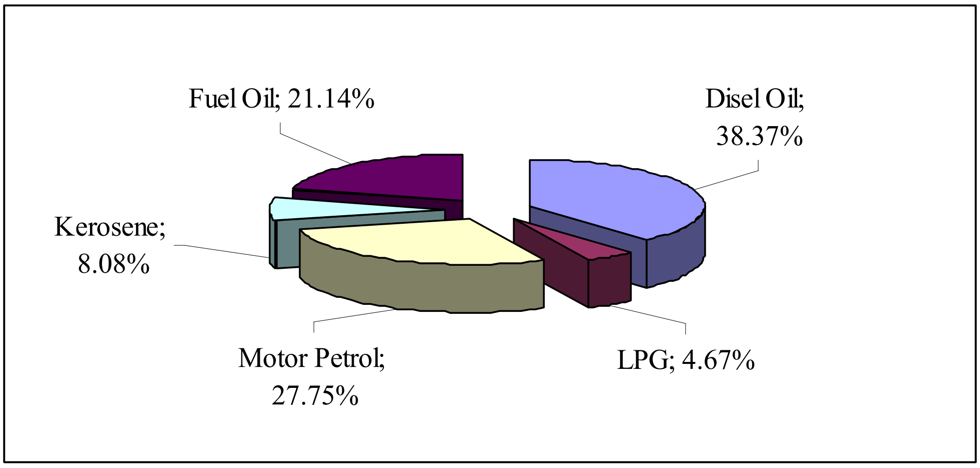

Fig. 1.1.Final consumption for petroleum product in 2008 of 88,227 million liters (Power 2010)

In Iran many strategies are conducted in order to decrease the fuel consumption. These strategies are explained in the next section. It must notice that using energy efficiently in order to keep the energy reserve available and also care about the environment are two important factors involved in the current global market. Therefore, many countries are implementing a policy for energy efficiency and transportation systems.

Also the fuel consumption of the world due to the type of fuel is shown in figure 1.2. The fossil fuel dependency in the world is decreased to 89.2% in the year 2009 (Annex, 2010).

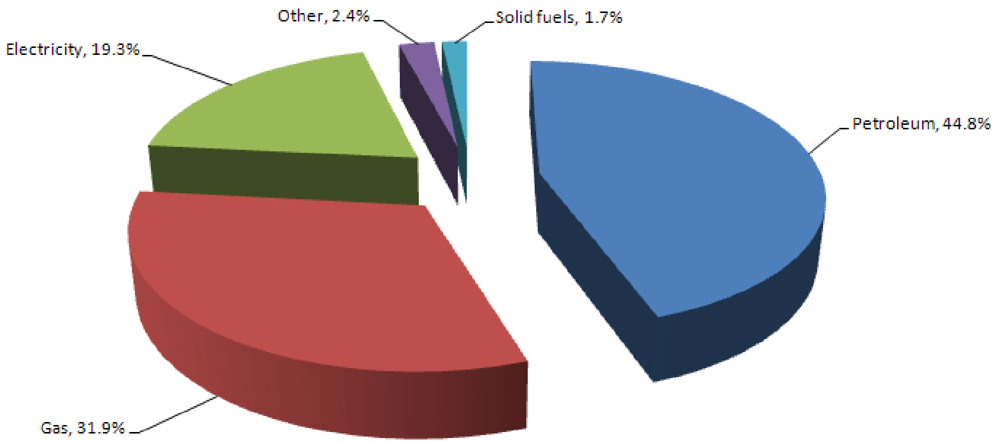

Fig. 1.2.Final fuel consumption of the world due to the type of fuel in 2009 (Annex, 2010)

There is also more information about the heavy duty vehicles in Iran. These data are brought together here in order to achieve the best result of label and standards. The essential data are used from this section. The following tables show these data.

The number of the lorry and trucks and buses are growth with the average annual rate of approximately 2.88 % and 4.85 %, respectively.

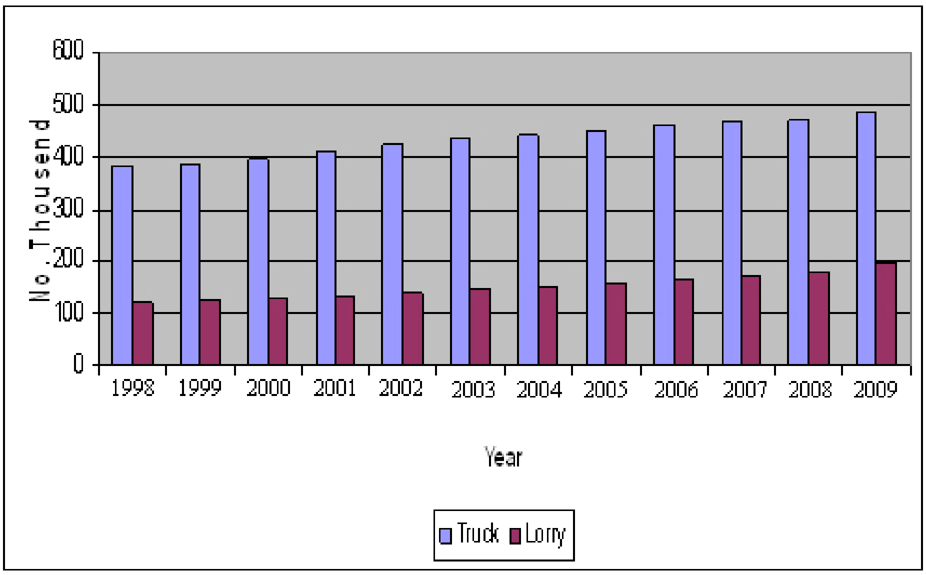

Fig. 1.3.Number of vehicles (Power 2010)

1.1.2 Iran energy policies

As mentioned before there are many number of vehicles in the transport fleet that consume the gasoline. In order to reduce the growth in consumption of oil products in Iran, the optimize fuel consumption organization defined the five as principles the main activities in the transportation sector. These principles are:

1. Improved methods of transportation
2. Technology for heavy duty vehicles
3. Technology for heavy duty vehicles
4. Development of improved fuel
5. Development of standards and fuel consumption

In this view, the main goal is reducing the consumption of petroleum products and reduction the amount of produced pollutants by used fuel in transportation is considered as a secondary target (IIES 2010).

National policies to reduce fuel consumption has been scheduled by both policies based price and non-price. The works which have been done in the based price policy in order to save energy are:

- To quota the gasoline and engine oil through smart card, controlling and reducing the consumption of these products
- To using natural gas (CNG) as alternative fuel in transportation sector
- To develop of public transportation system and the metro networks
- To develop and improve the facilities of technical examination centers, and testing all vehicles compulsory in order to reduce the fuel consumption, environmental protection and traffic safety
- To eliminate the old and retired cars in the private and public transportation systems

- To developed and improve the traffic management in country by building highways
- To train the methods of energy management for companies and factories

In based price policy of the country the economic development plan and the stepped pricing of gas program are implemented to remove energy subsidies; in order to scrounge and reduce energy consumption.

Transportation sector in Iran is largely dependent on the road vehicles. Motor vehicles ownerships have been promoted so that vehicle manufacturing industry is an important factor for economic development in Iran. Based on the type of fuel, motor petrol and diesel oil contribute 49.49 percent and 42.01 percent of total fuel consumption in the transportation sector, respectively. Therefore, as a starting point it is also necessary to concentrate to reduce energy consumption in transportation sector.

1.2 Objectives of research

Developing the fuel economy standards and labels for heavy duty vehicles in Iran is the major objective of this study. This program can help the country to reduce energy consumption, to gain economic benefits and environmental positive effect. Development and the implementation of fuel economy standards and labels reduce fuel consumption, especially in the transportation sector in a country. Decreasing the fuel consumption causes to reduce greenhouse gas emissions which have a negative impact on the environment. This case study can be summarized as follows:

- To chose a suitable test procedure to use in fuel economy program of heavy duty vehicles in Iran
- To suggest the fuel economy standards and labeling program for heavy duty vehicles in Iran

- To analysis of cost efficiency for potential fuel economy improvement and estimate cost fuel consumption in the future
- To calculate the potential financial savings and environmental impact of fuel economy standards and labeling program for heavy duty vehicles in Iran
- To anticipate changes in marketplace when the fuel economy standards and labels program is executed

1.3 Contributions of the research

This research is tried to use the available published or gathered data in the Iran. This study is essential that it will cause considerable contributions in energy demand in the future. This study includes the selection of appropriate test procedure, fuel economy standards and labels for heavy duty vehicles in Iran. However, the main contribution of this study is to develop a comprehensive strategy on the implementation of fuel economy standards and labels for heavy duty vehicles. The instructions include determining the specific steps of procedures, and also to ascertain the impact of fuel economy standards and labeling program for heavy duty vehicles.

1.4 The barriers of research

The collecting the valuable data is the essential step for doing each analysis or any approach. The precise characteristics of the input data must be known in order to develop the fuel economy standards and labels program satisfactorily. Like many other developing countries this information are not collected professionally in Iran. For the study, the data of the characteristics of the motor vehicles and their fuel consumption in transportation sector are essential. Unfortunately, the most critical data which is fuel economy of motor vehicles is not completely collected for this country. Such restrictions, the researcher had to use raw data from various sources in order to continue the analysis. Some data on the fuel economy of motor vehicles are collected from resources which have been provided by vehicles manufacturers. Other data that are needed for study have been taken from the various numbers of sources, including, published articles, national reports and governmental published journals.

1.5 Organization of the research project

The research project is divided into five. In each chapter the necessary information in order to conduct the objectives of research and the main one proposed the fuel economy standards and labels for heavy duty vehicles in Iran an their impacts are represented. In the chapter one the energy consumption of heavy duty fleet in Iran and background of the energy consumption policies, aims and the barriers of this research are explained. The current transportation system and energy situation in Iran is introduced in this chapter. The next chapter reviews related studies on the fuel economy standards and labeled. A comprehensive review is done to examine the relation of literatures reviewed and this study**.** The reviewed resources are journal articles, research reports and conference papers. The research methodology to develop test procedure, execute the fuel economy standards and labels, to present the methods for analyzing engineering/economic approach in order to calculate the changes in the market are gathered in chapter three. Also the method to calculate the impact on energy, economy and environment with respect to fuel economy standards and labels are represented. Chapter four includes the discussion of methodology for case of heavy duty vehicle in Iran and also the results of research carried out in pervious chapter are presented. Finally the present research results and recommendations are represented in the chapter five. In this section, the obtained results of study are summarized and recommendations are suggested to ensure a successful implementation of fuel economy standards and labels plan.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

The number of the vehicles of fleet especially heavy duty vehicles affect on the economic improvement of each country. Nowadays transportation sector plays a key role in daily Iranian life. The GDP grew at an average rate over 5.5% in Iran from 1998 to 2008 (Iran 2010a). Like many developing countries, the GDP growth continues to affect the growing of energy consumption demand in the nation (Dargay and Gately 1999). The increase in motor-vehicle ownership in the recent year clearly shows the growing of demand in the transportation sector as one of the most important sector in the energy consumption in Iran (Pucher, Park et al. 2005).

The transportation sector has the second largest contribution in oil products consumption in Iran. The transportation sector contributes around 269.8 million barrels oil equivalent (Mboe) of oil production in 2008 (Power 2010). The production of heavy and heavy-duty vehicle grew at an average rate over 12.2% and 17.7% in Iran from 2001 to 2009 respectively (Power 2010). The large number of vehicle has been one of the most effective issues in the increasing of petrol and gasoline fuel consumption during recent years.

Iranian government has implemented various policies and programs such as applying quote on petrol consumption and changing the policies of subsidizing of petrol for optimization of fuel consumption in the transportation sector during last 5 years ago. Therefore, it is really important to make consumer aware of fuel economy and influence their purchasing decision leading to a market transformation.

There are some strategies to guide the society in an effort to promote the motor vehicles which are more efficient in fuel. One of the most effective strategies is to implement a fuel economy standard (Clerides and Zachariadis 2008). Only the motor vehicles which has a fuel economy standards can be sold legally and the motor vehicles without suitable performance can not be entered the market. In fact, fuel economy standard identifies a bottom line of achievement and it performs as base line for the vehicle manufacturer.

In order to set up standards and labels program for motor vehicles in Iran, it is necessary to have an overview of other related studies regarding fuel economy standards and labels in the other countries. The energy policies, manufacturing structure, culture and climate are some issues which do not let us to use the successful standards and labels of the other countries, in Iran directly (Egan 1998). Despite this, it is possible to use these programs in some approaches and modify them when it is required base on conditions in Iran.

2.2 Program review: Test Procedure

Test procedure is a standardized pattern that is the basis of fuel economy standards and labels and green house gas (GHG) emissions. There are some standards test procedure in some different countries which shows the condition of urban and suburban driving. The test procedure also represents the traffic conditions and the driving culture in a city (Meier and Hill 1997). The characteristics in design and use of products are the most effective issues in the test procedure in different regions. The common test procedures are the European drive cycle, the US drive cycle and the Japanese drive cycle. Actually all the driving test cycles are divided into two sections, which are Chassis Dynamometer and Engine Dynamometer. These two methods are being used for evaluating the essential data like fuel consumption and the maximum momentum of the engine and the power generated. The explanation of each method is represented as follow, in summery.

2.2.1 Chassis Dynamometer Test Procedure

In this method the automobile is under the test totally. The chamber of vehicle and all the transmission system of vehicle are under the test. In this method the real condition of driving for a motor vehicle is simulated in laboratory in order to obtain the desired amount of test. The following pictures show the sample of chassis dynamometer test.

Fig.2.1 Chassis Dynamometer Test Procedure

According to the condition of test the wind tunnel also can be simulated in order to achieve the aerodynamic component of vehicle. The following picture shows the condition of test without considering to the aerodynamic of vehicle. Actually this parameter is mostly are discussed in light duty vehicles. This type of testing sometimes is used if the utilization of heavy duty engine is identified.

Fig.2.2 Chassis Dynamometer Test Procedure

2.2.1 The Engine Dynamometer Test Procedure

This method is usually used for heavy duty vehicles in order to determine the emission reduction or the fuel consumption of the vehicle. This is for the engines that the duty of them does not have any effect on the test.

Fig.2.3 Engine Dynamometer Test Procedure

This test is using for the diesel engines that the output power can be determined. The achieved characteristics of engine can consider any way independent of the chamber of vehicle.

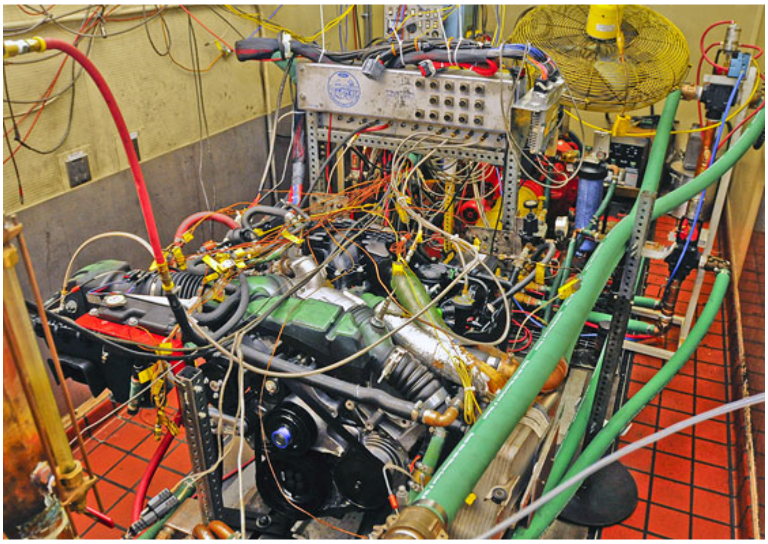

Fig.2.4 Engine Dynamometer Test Procedure

Nevertheless a dynamometer can also be used to determine the torque and power needed to operate a driven machine such as a pump. In that case, motoring or driving dynamometer is more useful. A dynamometer that is planned to be driven is called an absorption or passive dynamometer. Although a dynamometer that can either drive or absorb is also called a universal or active dynamometer.

In addition for the usage of determination the torque or power characteristics of a machine under test (MUT), dynamometers are utilized in a number of other roles. In the spite of testing cycles such as those defined by the US Environmental Protection Agency (US EPA), the standard emissions dynamometers are used to provide simulated road loading of either the engine (using an engine dynamometer) or full power train (using a chassis dynamometer). As a matter of fact, beyond simple power and torque measurements, dynamometers can also be used as part of a test bed for a diversity of engine development activities such as the calibration of engine management controllers, detailed investigations into combustion behavior and tribology (mechanical engineering).

In the medical terminology, hand-held dynamometers are more useful for routine screening of grip, because it's more easy to hold it fast or firmly and also for hand strength and initial and ongoing evaluation of patients that currently happening with hand injury or dysfunction like any disturbance in the functioning of an organ or body part. They are also used to measure grip strength in patients where expose of the cervical (Relating to or associated with the neck) nerve roots or peripheral or incidental nerves is suspected.

Force dynamometers are mostly used for measuring the strength of athletes, patients, and workers at the back, grip, arm, and leg in the rehabilitation, physiology of kinesiology, and ergonomics realms in order to evaluate physical status, performance, and task demands. Generally for converting the measurement of the force applied to a lever or through a cable to a moment of force it is needed to multiplying the vertical distance from the force to the axis of the level.

The differences in these cycles are in the terms of speed profiles, acceleration and declaration profile, duration in standards and frequencies of starts and stops. These factors cause the different fuel economy rating for the same car models under these test cycles (An and Sauer 2004).

2.3. The common test cycles for heavy duty vehicles

2.3.1. The International test cycles

2.3.1.1 World Harmonized Stationary Cycle (WHSC)

The WHSC test is an engine dynamometer schedule steady-state which has defined by propose of global technical regulation (GTR) and developed by the UN ECE GRPE group. The GTR is covering world harmonized heavy duty certification (WHDC) process for engine exhaust emissions worldwide. Hot start steady state test cycle (WHSC) and a transient test cycle (WHTC) are considered as two test cycles with both cold and hot start point necessities which have created to cover typical driving situation in the EU, USA, Japan and Australia.

The WHSC can be considered as a steady-state test cycle in kind of ramp situation with a sequence of steady state engine test modes which defines speed and torque criteria at each mode, plus, it defined ramps between these modes. The parameters of the WHSC have shown in Table 2.1.

Table 2.1 World Harmonized Stationary

Mode	Speed (%)	Load (%)	Weighting Factor	Mode Length (sec)
0	Motoring	-	0.24	-
1	0	100	0.085	210
2	55	25	0.02	50
3	55	70	0.1	250
4	55	100	0.03	75
5	35	25	0.02	50
6	25	70	0.08	200
7	45	25	0.03	75
8	45	50	0.06	150
9	55	100	0.05	125
10	75	50	0.02	50
11	35	50	0.08	200
12	35	25	0.1	250
13	0	0	0.085	210
Sum			1	1895

The WHSC runs from a hot start point which is following engine precondition at mode 9. The idle mode is included of two modes, first mode 1 at the beginning and second, mode 13 at the end of the test cycle. First mode which is mode 0 does not run, I mean it's only calculating in mathematic calculations by a weight factor which is equal to 0.24, plus, emissions and power of zero.

The real cycle's job is calculated by integrating actual engine power over the cycle and calculating the brake specific emissions. The weighting factors (WF) are given only for reference.

2.3.1.2. World Harmonized Transient Cycle (WHTC)

The WHTC test is a transient engine dynamometer schedule which has defined by the global technical regulation (GTR) suggestion and developed by the UN ECE GRPE group. The GTR is covering worldwide harmonized heavy-duty certification (WHDC) process for engine exhaust emissions. The proposed regulation is based on the worldwide use patterns of heavy commercial vehicle. Representative test cycles can be considered in two cases, first transient test cycle (WHTC) with both cold and hot start point requirements, second hot start steady-state test cycle (WHSC) which have formed to cover typical identified driving conditions in the EU, USA, Japan and Australia.

The WHTC is a transient test which takes 1800s to be done with several motoring segments during its process. Engine speed and torque values over the WHTC cycle which have normalized are schematically demonstrated in figure 2.5.

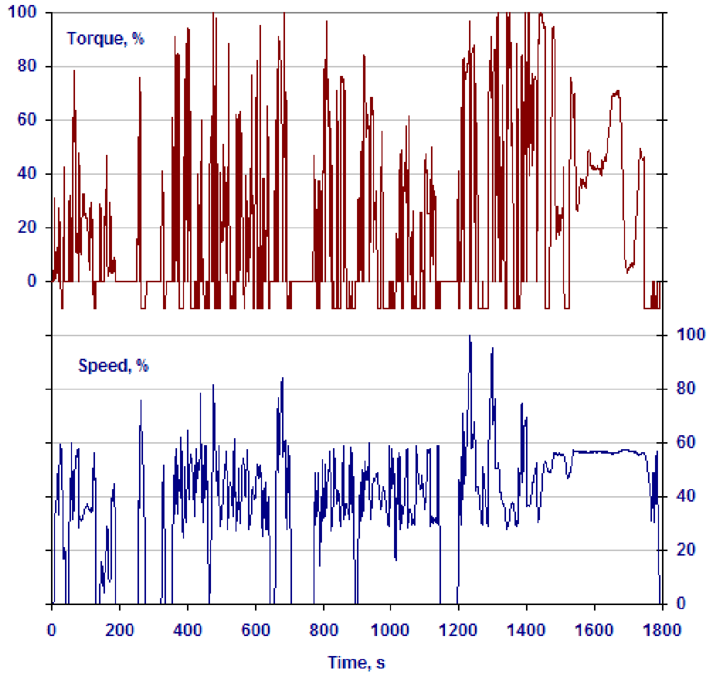

Fig.2.5.World Harmonized Transient Cycle (WHTC)

2.3.2. European Union

2.3.2.1. ECE R49

The R49 is 13-mode steady-state diesel engine test cycle which have introduced by ECE Regulation No.49 and then adopted by the EEC (EEC Directive 88/77, EEC Journal Official L36). It had been using for approval emission testing type of heavy-duty highway engines through the Euro II emission standard. Effective October 2000 (Euro III), the R49 cycle was replaced by the ESC program.

Table 2.2 ECE R49 and US 13-mode Cycles

Mode	Speed (%)	Load (%)	Weighting Factor R49	Weighting Factor US
1	Idle	-	0.25/3	0.20/3
2	maximum torque speed	10	0.08	0.08
3		25	0.08	0.08
4		50	0.08	0.08
5		75	0.08	0.08
6		100	0.25	0.08
7		-	0.25/3	0.20/3
8	Idle	100	0.1	0.08
9	rated power speed	75	0.02	0.08
10		50	0.02	0.08
11		25	0.02	0.08
12		10	0.02	0.08
13	Idle	-	0.25/3	0.20/3

The R49 test is executed on an engine dynamometer operated through a sequence of 13 conditions of speed and load. Exhaust emissions are measured at each mode expressed in g/kWh. The result of final test is a weighted average of the 13 modes. The test conditions and weighting factors of the R49 cycle are shown in Table 1 and in Figure 1. The areas of circles in the graph are depending on the weighting factors for the modes respectively.

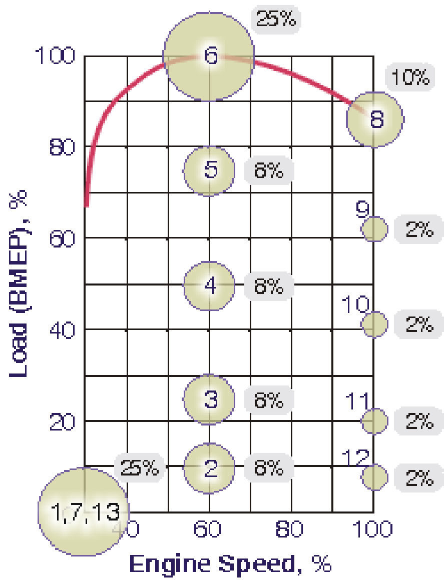

Fig.2.6. ECE R49 Cycle

The R49 test cycle has operating conditions which are identifying US 13-mode cycle. However, the weighting factors are different. Due to weighting factors are high for 6^{th} and 8^{th} modes (high engine load), the European cycle is characterized by high average exhaust of gas temperatures.

2.3.2.2. European Stationary Cycle (ESC)

The ESC test cycle which also has known as OICA/ACEA cycle has introduced with the ETC (European Transient Cycle) and the ELR (European Load Response) tests together for certifying emission of heavy-duty diesel engines in Europe which have been starting since the year 2000 (Directive 1999/96/EC of December 13, 1999). The R-49 test have replaced by The ESC which is a steady-state process having 13-mode.

The engine is tested on engine dynamometer over a sequence of steady-state modes (table 2.3, figure 2.7). The engine must be operated by taking specified time in each mode by completing engine speed and load changes in the first 20 seconds. The specified speed shall be held within ±50 rpm and the specified torque shall be held within ±2% of the maximum torque at the test speed. Emissions are measured and recorded during each mode and over average records; the cycle is using a set of weighting factors. Emissions of the particulate matters are sampled on one filter over the 13 modes. The final emission results are going to be reported in gr/kWh.

Table 2.3.ESC Test Mode

Mode	Engine Speed (%)	Load (%)	Weighting Factor (%)	Duration (minute)
1	Low idle	0	15	4
2	A	100	8	2
3	B	50	10	2
4	B	75	10	2
5	A	50	5	2
6	A	75	5	2
7	A	25	5	2
8	B	100	9	2
9	B	25	10	2
10	C	100	8	2
11	C	25	5	2
12	C	75	5	2
13	C	50	5	2

The certified personnel may request for additional random testing modes within the cycle control area during emission certification testing (Fig 2.7). Maximum emissions at these extra modes are influenced by interpolating between results from the close regular test modes.

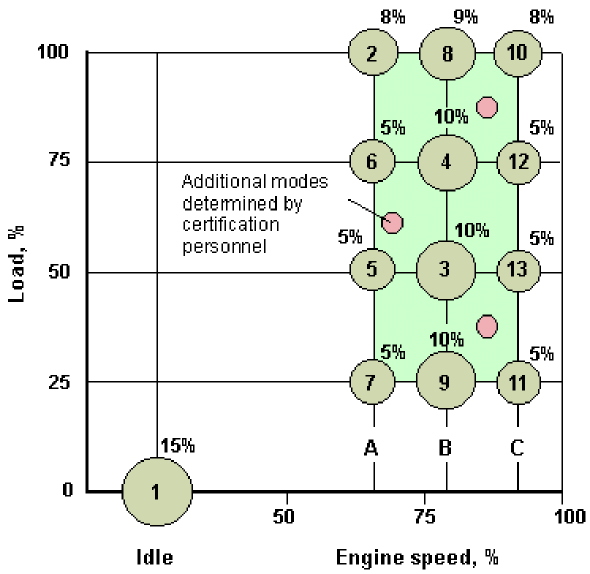

Fig.2.7. ESC Test Mode

The engine's speeds are defined as follow:

The high speed n_{hi} is determined by calculating of 70% of the maximum net power which declared. The highest engine speed where this power value occurs (i.e. above the rated speed) on the power curve is defined as n_{hi}.

The low speed n_{lo} is determined by calculating of 50% of the maximum net power that declared. The lowest engine speed where this power value occurs (i.e. below the rated speed) on the power curve is defined as n_{lo}. The engine speeds A, B, and C which have used during the test are going to be calculated from the following formulas:

$$A = n_{lo} + 25\% \times (n_{hi} - n_{lo}) \qquad (2.1)$$

$$B = n_{lo} + 50\% \times (n_{hi} - n_{lo}) \qquad (2.1)$$

$$C = n_{lo} + 75\% \times (n_{hi} - n_{lo}) \qquad (2.1)$$

where n_{hi} is the high rotate which is obtained based on the 70% of the determined net power and n_{lo} is the low rotate which is obtained based on the 50% of the determined net power. The following diagram shows the location of them.

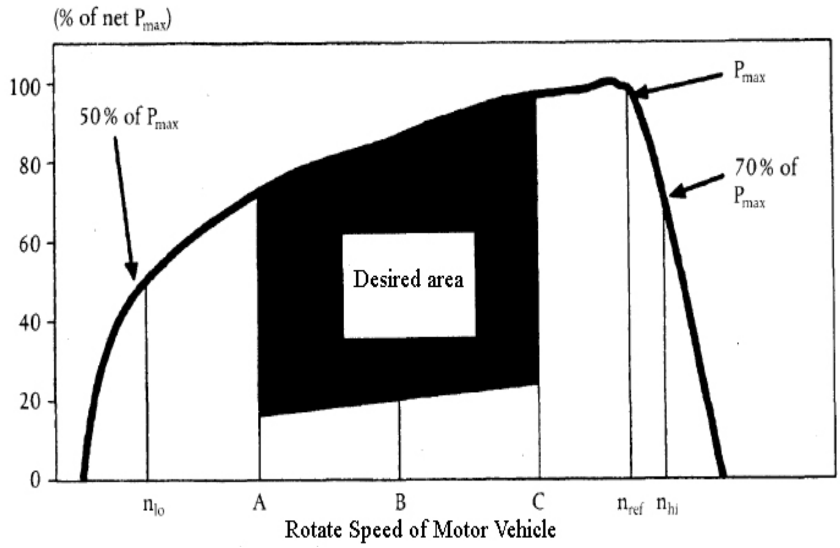

Fig.2.8.The power diagram of engine (Mirzaee 2008)

The ESC test is characterized by high average load factors and high temperature exhausted gas.

2.3.2.3. European Load Response (ELR)

The Euro III emission regulation has introduced The ELR engine test in effective year 2000, with regard to smoke opacity measurement from heavy-duty diesel engines (Directive 1999/96/EC).

The test consists of three load steps after each other which at each of the three engine speeds A (cycle 1), B (cycle 2) and C (cycle 3) which have followed by cycle 4, at the specific speed which is between speed of A and speed of C and a load between 10% and 100%, selected by the certified clients and operators. A, B, and C are having speeds which are defined in the ESC cycle. The sequence of dynamometer operation on the test engine is demonstrated in figure 2.9.

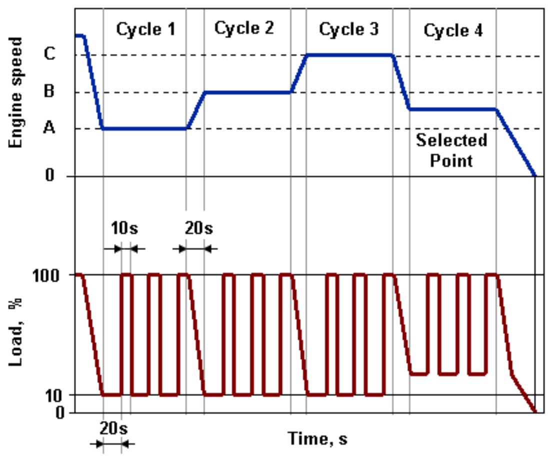

Fig.2.9. ELR Test

Measuring the values of smoke are continuously recorded during the ELR test with a frequency of at least 20 Hz. Then the smoke traces are going to be analyzed to determine the final smoke values by calculating them. First, by using specific averaging algorithm, average of smokes values are going to take over first second time interval. Second, load step of smoke values are determined as the highest first average value at each of the three load steps for each of the test speeds. Third, mean of the values of the smocks for each cycle (test speed) are calculated as arithmetic averages from the cycle's three load step smoke values. The final smoke value is determined as a weighted average from the mean values at A (weighting factor 0.43), B (0.56), and C (0.01) speeds.

2.3.2.4. European Transient Cycle (ETC)

The ETC test cycle has been introduced with the ESC (European Stationary Cycle) to certify emission of heavy-duty diesel engines in Europe starting in the year 2000 (Directive 1999/96/EC). The ESC and ETC cycles have replaced instead of the earlier R-49 test.

The ETC cycle has been developed by the FIGE Institute which also was known as FIGE transient cycle in the beginning in Aachen, Germany. It was based on real road cycle measurements of heavy duty vehicles. The final ETC cycle is a shortened and briefed modified version of the original FIGE project.

Different driving situations are represented by three segments of the ETC cycle which is included urban, rural and motorway driving conditions. The duration of the entire cycle is 1800s consists of duration of each part which is 600s. Part one is representing driving in the city with maximum speed of 50 km/h, frequent starts, stops, and waste times. Part two is rural driving starting by increasing acceleration segment and the average of speed is about 72 km/h. Part three is including motorway driving with average speed of about 88 km/h.

FIGE Institute has developed the test cycle by two variables first as chassis and second as engine dynamometer test. Vehicle speed versus time over the duration of the cycle is demonstrated in figure 2.10 (the vehicle version of the FIGE cycle has not standardized). The ETC cycle is performed on an engine dynamometer due to engine certification and type approval. Related engine speed and torque curves are shown in figures 2.11 and 2.12.

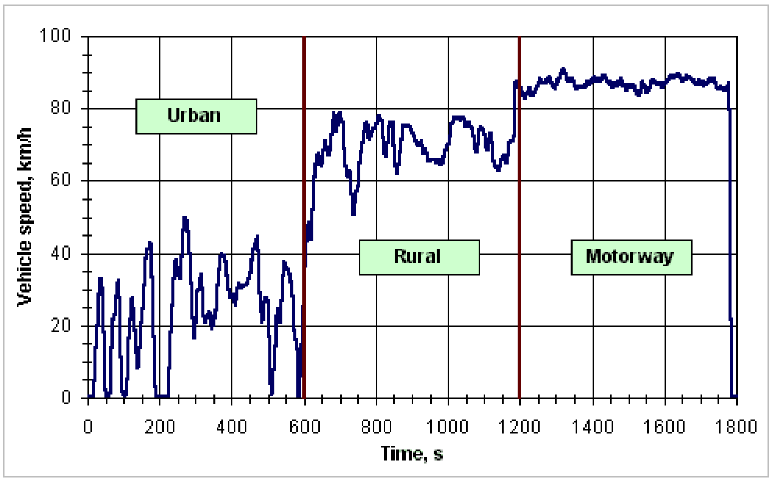

Fig. 2.10

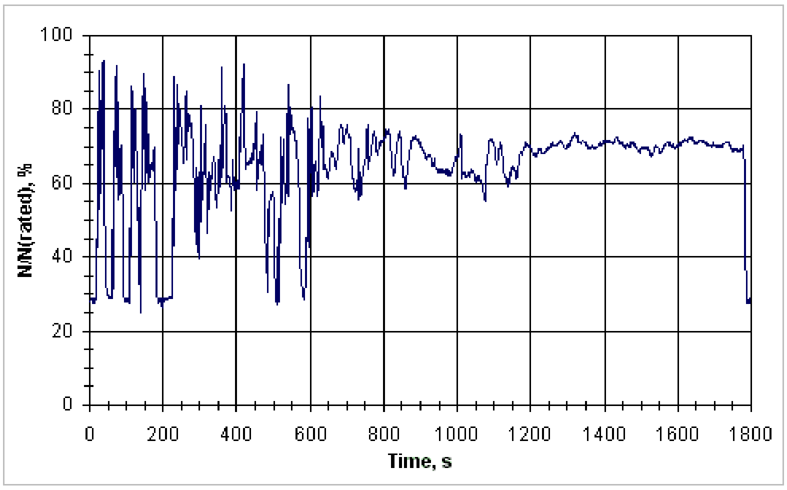

Fig. 2.11

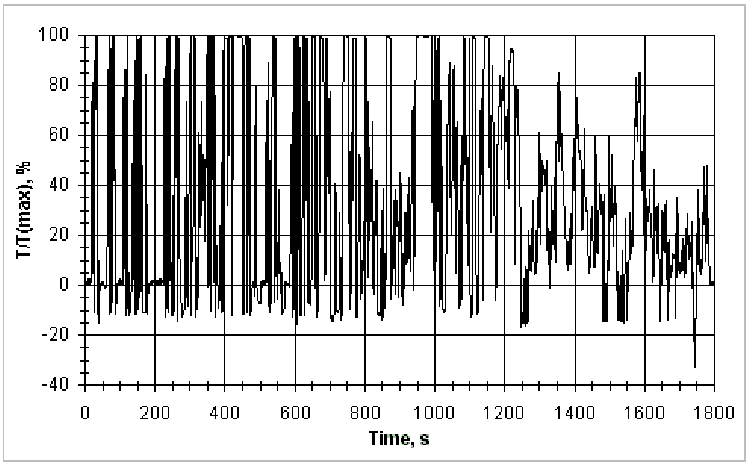

Fig. 2.12

2.3.2.5. Braunschweig City Driving Cycle

Technical University of Braunschweig has developed the Braunschweig City Driving Cycle. It is simulating temporary driving bus in urban area with frequent stops driving schedule. The cycle performed on a chassis dynamometer. The following can be considered as characteristics of the cycle:

- Duration: 1740 s
- Average speed: 22.9 km/h
- Maximum speed: 58.2 km/h
- Idling time: about 22% (the first and last idle segments not included)
- Driving distance: about 11 km

Speed of the vehicle during the cycle's time is shown in figure 2.13.

The Braunschweig Cycle had been one of a very few heavy-duty transient cycles in Europe. It was regularly used in various research projects and programs as well as some equipment which was using in certification programs. The role of the Braunschweig cycle is likely to be diminished by introducing transient ETC cycle. Studies on Comparing the ETC produces demonstrates that it has 40% lower power output and 30 - 70% lower regulated emissions in comparison with the Braunschweig cycle.

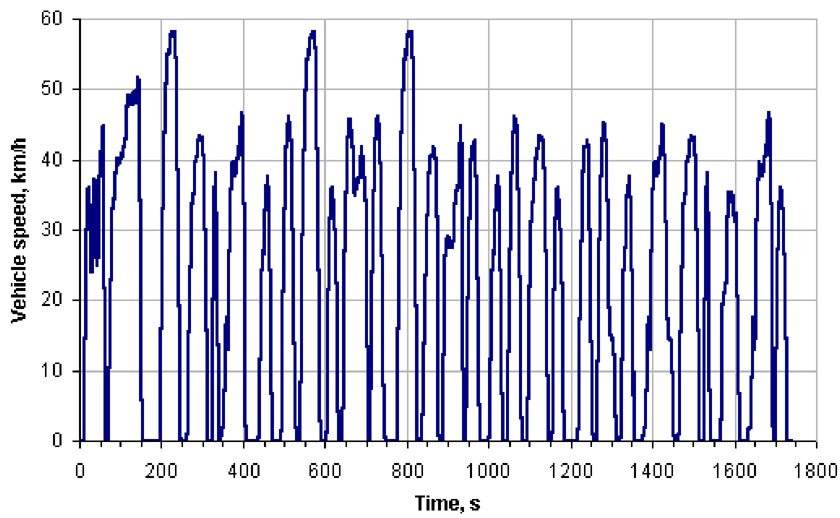

Fig. 2.13

2.3.3. Australia

2.3.3.1. CUEDC (Diesel)

In 1998 the Australian National Environment Protection Commission was as a part of the Diesel National Environment Protection Measure that licensed the development of the Composite Urban Emissions Drive Cycles (CUEDCs). The Data for this development was collected in Sydney, Australia. In 2005, a Petrol CUEDC was developed for light-duty gasoline vehicles.

In according to closely reduplicate actual Australian on-road urban driving CUEDCs were created. CUEDCs are used for chassis based dynamometer testing of both heavy and light vehicles. Actually most of them are composed of four distinct and manifest drive cycle segments: congested, minor roads, arterial and highway. Totally a set of the four CUEDC segments takes about 30 minutes. For each of the major diesel powered vehicle categories ranging different CUEDCs were developed from off-road passenger vehicles and light goods vehicles to heavy combination vehicles. In general there are six CUEDC cycles, there is one unique cycle for each of the six ADR vehicle categories: MC, NA, NB, ME, NC, NCH. Description of each cycle is shown in the figures 2.14 to 2.19.

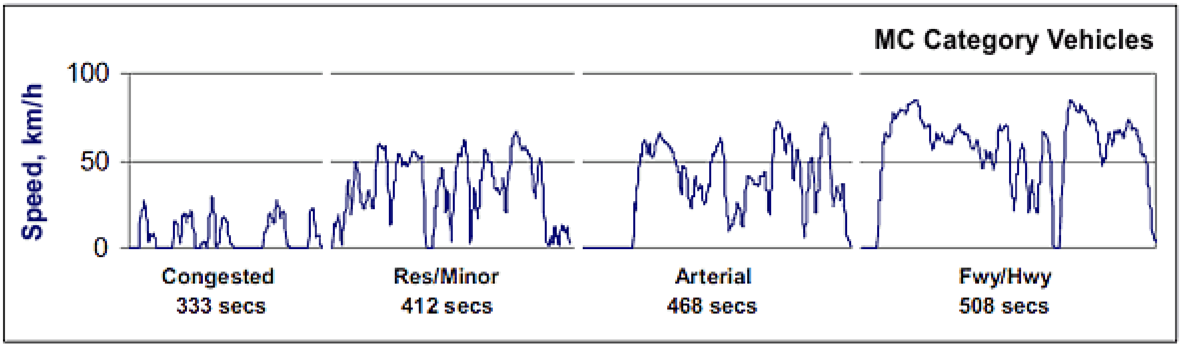

Fig. 2.14

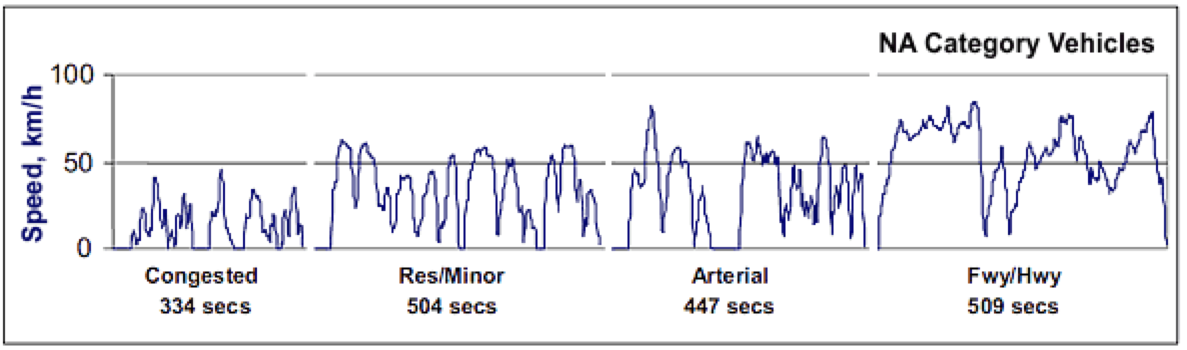

Fig. 2.15

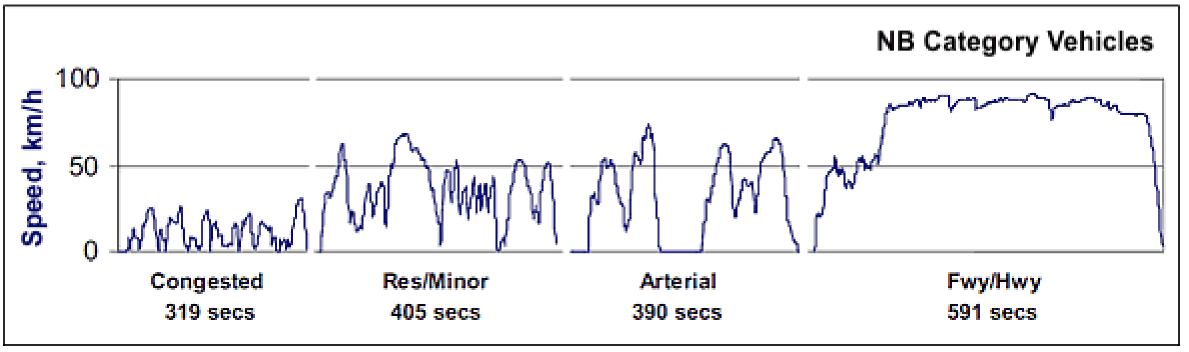

Fig. 2.16

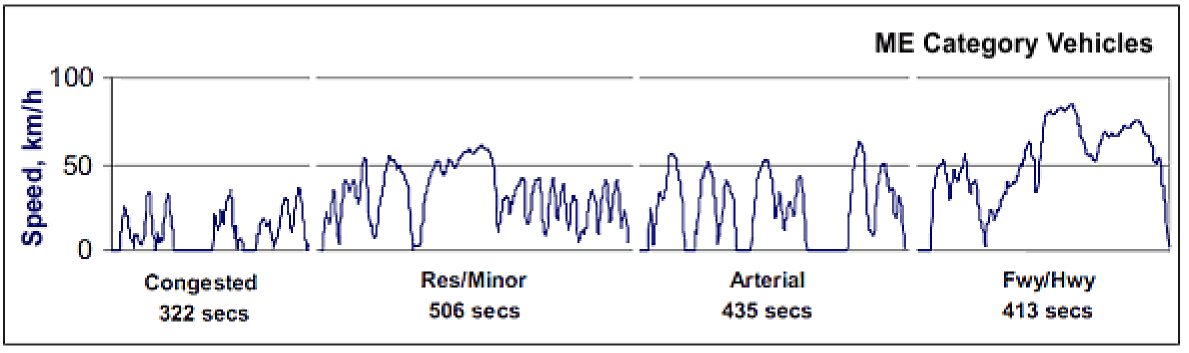

Fig. 2.17

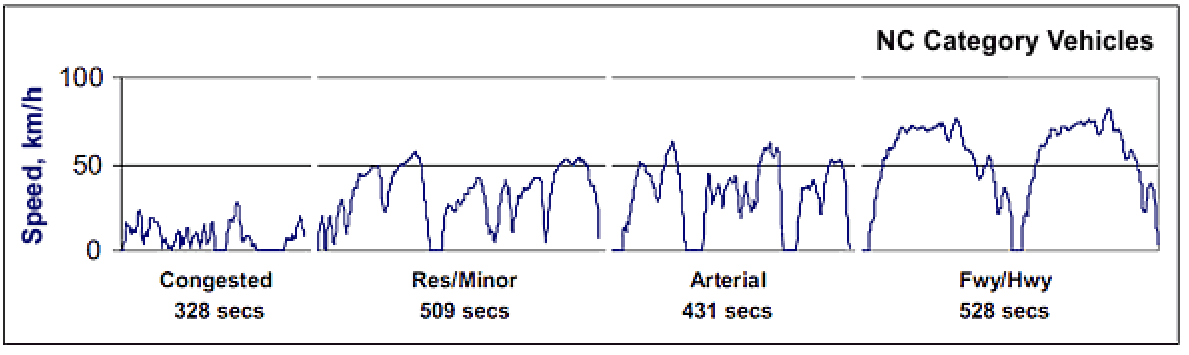

Fig. 2.18

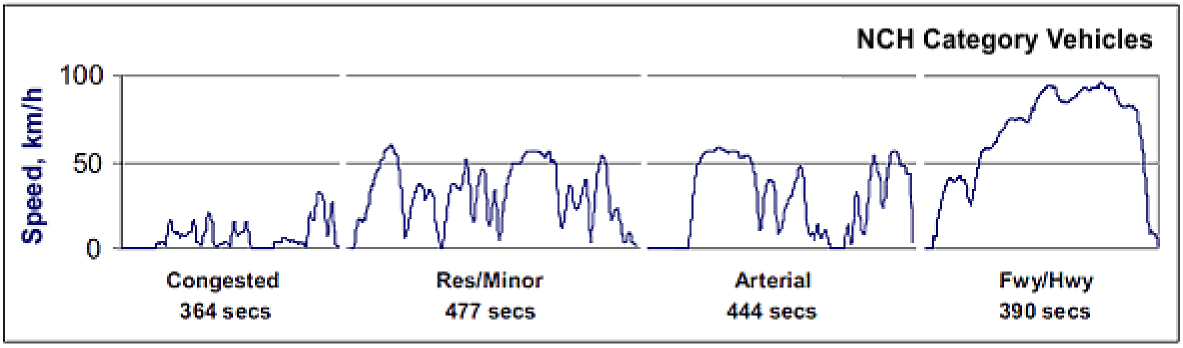

Fig. 2.19

2.3.4. Japan

2.3.4.1. Japanese 6 Mode

There was a cycle in Japan that was used for heavy duty engines which name was 6-mode cycle. But today it has been replaced by the newer 13-mode cycle which has only historical significance.

This engine was tested over 6 different speed and load conditions. The modes were run in sequence and the duration of each mode was 3 min. Besides Emissions were measured at each mode then it averaged over the cycle using a set of weighting factors. The final test result was conveyed as volumetric concentration in ppm.

Generally there were two definitions of the test modes and weighting factors: one of them was for diesel engines and the other one was for gasoline and LPG engines. The table below demonstrates the list of the diesel cycle parameters.

Table 2.4.Japanese Diesel 6 Mode Cycle

Mode	Speed(% of nominal)	Load (%)	Weighting Factor
1	idle	-	0.355
2	40	100	0.071
3	40	25	0.059
4	60	100	0.107
5	60	25	0.122
6	60	75	0.286

2.3.5. USA

2.3.5.1. WVU 5-Peak Cycle (Chassis Dynamometer)

In 1994 this cycle was developed by the Vehicle Emissions Testing Laboratory at West Virginia University. The WVU 5-Peak cycle (or Truck cycle) was designed in order to test the general truck chassis. This cycle contains of five segments, that each of them are with an acceleration to a peak speed, which followed by a brief steady state operation and then a deceleration back to idle. Severally the five peak speeds are 20, 25, 30, 35, and 40 mph (Figure 2.20).

The characteristic parameters of the cycle are as below:

- Duration: 900 s
- Driving distance: 5 mile

A modification of the cycle that existed above, known as the “WVU 5-Miles Route”. In the altered and adjusted cycle, the vehicle accelerated to each steady speed that using the highest possible acceleration. On both cycles there were some similarities such as the driving distance, time, and steady state speeds.

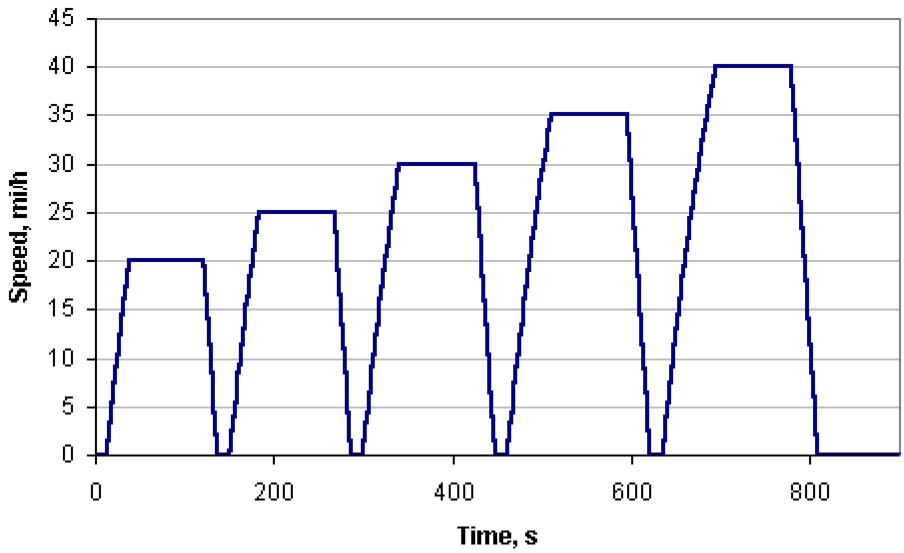

Fig. 2.20

2.3.5.2. Heavy Heavy-Duty Diesel Truck (HHDDT) Schedule

The Heavy Heavy-Duty Diesel Truck (HHDDT) schedule is a chassis dynamometer test developed by the California Air Resources Board with the cooperation of West Virginia University.

The test includes of four speed-time modes, that consists of idle, creep as it is shown in figure 2.21 and transient that can be seen in Figure 2.22 and high speed cruise according to the figure 2.23.

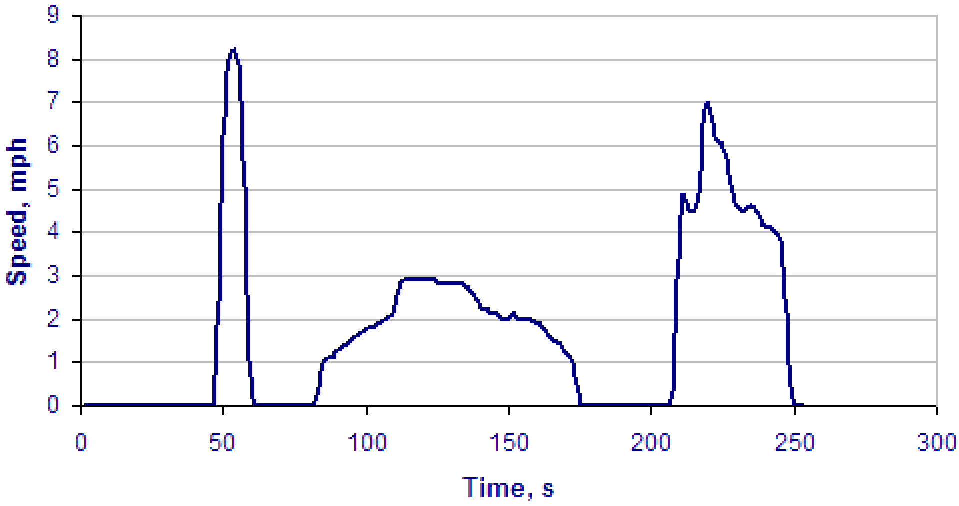

Fig. 2.21

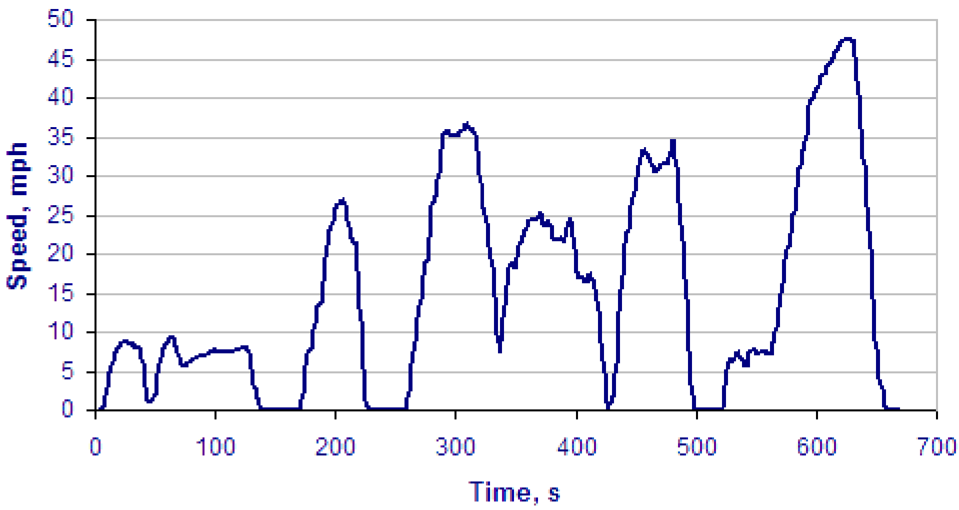

Fig. 2.22

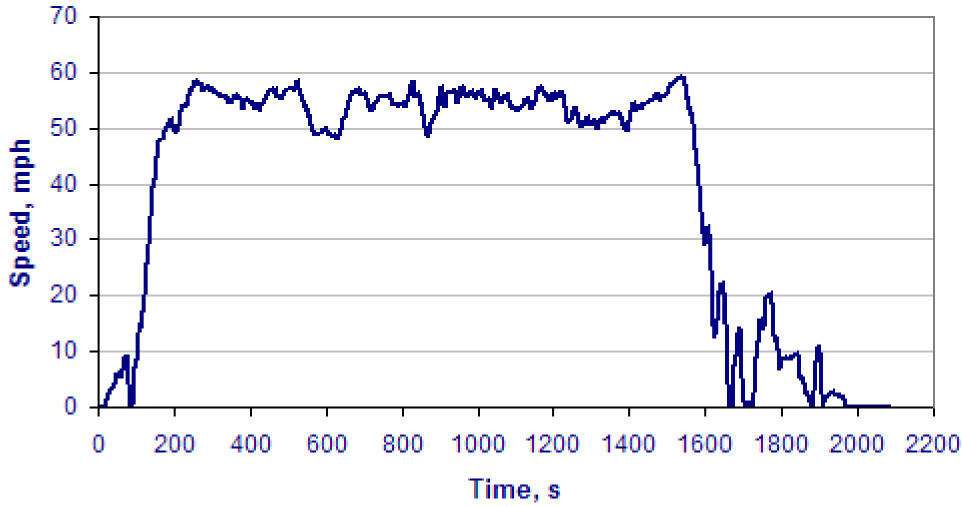

Fig. 2.23

Table 2.5.Statistics for HHDDT

Parameter	HHDDT Creep	HHDDT Transient	HDD Cruse	UDDS
Duration, s	253	668	2083	1063
Distance, mile	0.124	2.85	23.1	5.55
Average Speed, mph	1.77	15.4	39.9	18.8
Stops/Mile	24.17	1.8	0.26	2.52
Max, Speed, mph	8.24	47.5	59.3	58
Max, Acceleration, mph/s	2.3	3	2.3	4.4
Max, Deceleration, mph/s	-2.53	-2.8	-2.5	-4.6
Total KE, mph2	3.66	207.6	1036	373.4
Percent IDLE	42.29	16.3	8	33.4

2.3.5.3. Heavy-Duty FTP Transient Cycle (Engine Dynamometer)

The FTP (Federal Test Procedure) that is known as heavy duty transient cycle is currently used for emission testing of heavy duty for on road engines in the USA. The reason of developing the transient test was to allow the variety of heavy duty truck and buses in American cities that consists of traffic inside or around the cities on roads and expressways. However the FTP transient test is totally based on the UDDS chassis dynamometer driving cycle. This cycle contains of “motoring” segments so that, requires a DC or AC electric dynamometer that can be capable of both absorbing and supplying power.

The transient cycle comprises of four phases: the first phase is a NYNF (New York Non Freeway) that is a typical phase of light urban traffic with frequent and constant stops and starts, the second phase is LANF (Los Angeles Non Freeway) that is known as typical phase of crowded urban traffic with few stops, the third phase is a LAFY (Los Angeles Freeway) this phase is called simulating phase crowded expressway traffic in Los Angeles, and the fourth phase the same as the first NYNF phase. It contains of a cold start after a parking overnight that is followed by idling, acceleration and deceleration phases, and a wide range of different speeds and loads determined to simulate and reproduce the running of the vehicle that corresponds to the engine which being tested. The average load factor for the stabilized running conditions are about 20 to 25% of the maximum horsepower available at a given speed. Moreover there are just a few of this running conditions are available. Actually the cycle is accomplished twice then the second repetition is made with a warm start after a stop of 1200 s (20 min) on completion of the first cycle. The approximate average speed for this kind of cycle is about 30 km/h and the equivalent distance traveled is 10.3 km for a running time of 1200 s. The alteration of normalized speed and revolution and torque with time is illustrated in figure 2.24.

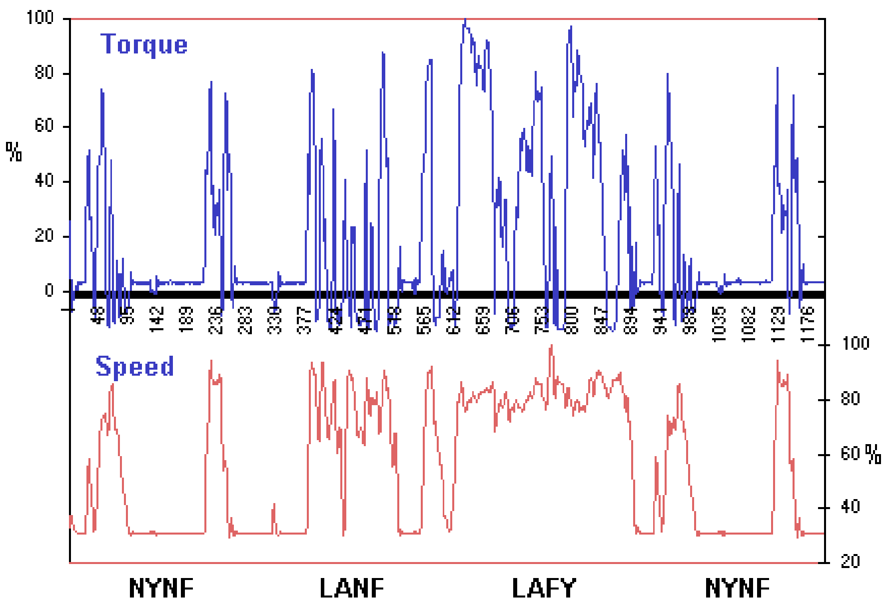

Fig. 2.24

The average load factor of the FTP cycle is roughly 20-25% of the maximum engine horsepower available at a given engine speed. The production of the FTP cycle for medium to high exhaust gas temperatures is tested in Heavy duty diesel engines. Generally, in most cases the temperature is at a medium level between 250 and 350°C, but still there are some hot sections with temperatures reaching as high as 450°C.

2.3.5.4. EPA Urban Dynamometer Driving Schedule (UDDS) for Heavy-Duty Vehicles (Chassis Dynamometer)

The important reason of developing the EPA Urban Dynamometer Driving Schedule (UDDS) was for chassis dynamometer testing of heavy-duty vehicles. It is sometimes pertained as "cycle D". The HD-UDDS cycle should not be miscellaneous with the FTP-72/LA-4 cycle for light-duty vehicles, which is also termed UDDS.

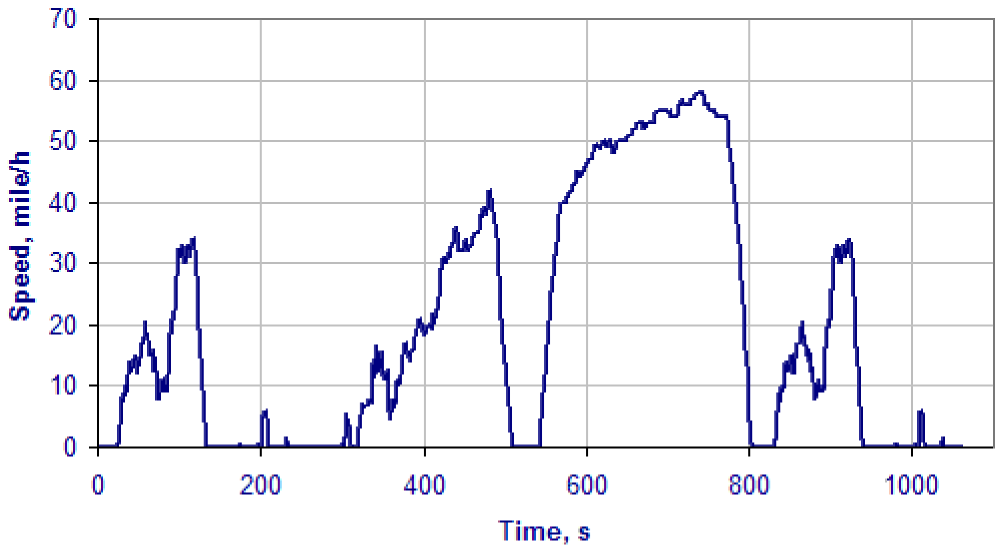

Fig. 2.25

The following are basic parameters of the cycle:

- Duration: 1060 seconds
- Distance: 5.55
- Miles = 8.9 km
- Average speed: 18.86 mi/h = 30.4 km/h

- Maximum speed: 58 mi/h = 93.3 km/h

The basis for the development of the FTP transient engine dynamometer cycle was The UDDS schedule

2.4. Program review: Fuel Economy Standards

Today, controlling energy consumption and reducing greenhouse gas emissions is one of the important issues in many countries. In this regard, the fuel economy standards and labeling program is a powerful tool and many countries are using or are planning to use this program. Many of the methods and policies have been used to reduce fuel consumption in the transportation sector. A number of different methods for reducing fuel consumption in the transportation sector are: fuel taxes. Fiscal incentives, research and development programs, technology mandates and targets, traffic control measures.

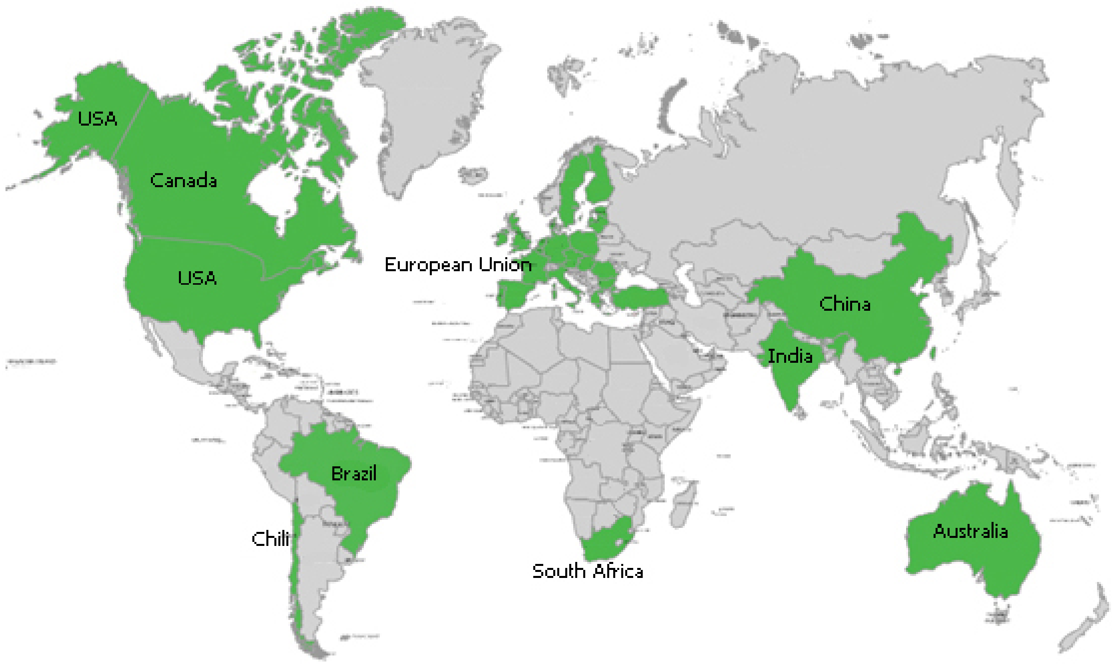

Fig. 2.26

2.5. Program review: Fuel Economy Label

One of the purposes of fuel economy label is, to provide the useful information about the car for consumers. The main items that can be obtained from a fuel economy label are (Raimund and Fickl 1998):

- To make consumers aware in order to purchase fuel efficient motor vehicles and, therefore, leading to a market transformation. Consider to the fuel economy label information, customers can purchase the motor vehicle which is more efficient and environmentally friendly The fuel efficient motor vehicles not only reduce the emission of CO_2 but save fuel and maintenance costs.
- To affect motor vehicle manufacturers to improve the fuel economy in engine production.
- To increase awareness of fuel economy and carbon dioxide emissions and to effect on driving behavior.

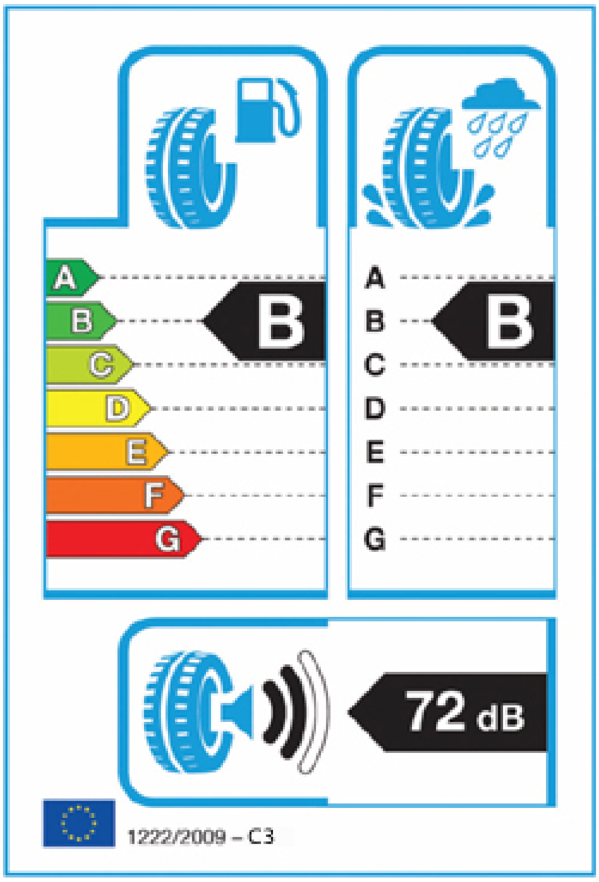

Fig. 2.27

The fuel economy label is an inexpensive method for influencing customer behavior and market development and encouraging manufacturers to produce cars with efficient engines. The design of the motor vehicle fuel economy label is taken from the household appliance energy label in some countries. This helps the fuel label become familiar for consumers. The cars label which includes energy and environment information will be recognized by costumers, if they be aware of the appliance labels (Du Pont 1998).

In some countries, like Austria, the fuel economy labels have been categorized to bar type comparative label with 7 letter grades. The grade A as the best class and grade G as the worst one are placed at the top and the bottom of label respectively. The grade of each motor vehicle is determined by a black arrow which is located in the next of its related bar (Sustainability 2011). Also, figures 2.28 shows the samples of the fuel economy label which was used in Denmark and England (GreenLabelsPurchase 2011).

The design of the fuel economy label in Canada is the same as the United States, the Canada fuel economy, shows the city and highway fuel economy in terms of both km/L and mpg. The estimated annual fuel cost is shown in a graphical form of fuel pump.

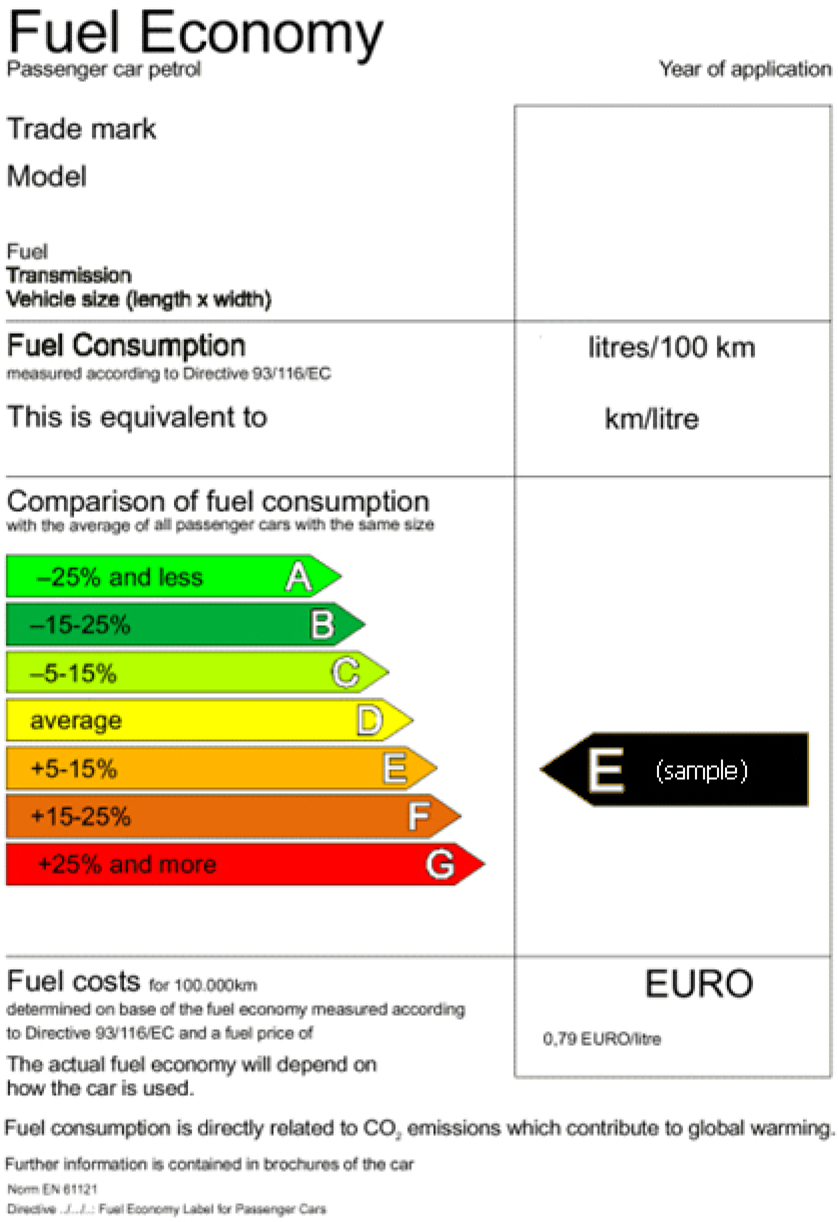
Fuel Economy
Passenger car petrol
Year of application
Trade mark
Model
Fuel
Transmission
Vehicle size (length x width)
Fuel Consumption
measured according to Directive 93/116/EC
litres/100 km
This is equivalent to
km/litre
Comparison of fuel consumption
with the average of all passenger cars with the same size
–25% and less A
–15-25% B
–5-15% C
average D
+5-15% E
+15-25% F
+25% and more G
E (sample)
Fuel costs for 100.000km
determined on base of the fuel economy measured according
to Directive 93/116/EC and a fuel price of
EURO
0,79 EURO/litre
The actual fuel economy will depend on
how the car is used.
Fuel consumption is directly related to CO2 emissions which contribute to global warming.
Further information is contained in brochures of the car
Norm EN 61121
Directive ../../..: Fuel Economy Label for Passenger Cars

Fig. 2.28

CHAPTER 3
METHODOLOGY

3.1 Introduction

In this chapter which is the foundation of research is explained. According to the previous chapter the essential information about fuel economy of heavy duty vehicles are collected and the situation of research is cleared in the world. This study attempts to promote and develop the fuel economy standard and label for motor vehicles in Iran. In this study, the data related to fuel economy of imported or produced vehicles in Iran, has been collected. Also the pattern of ownership of vehicle and fuel consumption has been provided. At the same time, the suitable test procedure is selected as the basis for the fuel consumption standard. Statistical and engineering economic approaches have been used to develop the fuel economy standard and calculate its potential improvement, respectively. All these steps are conducted based on the research which has been done before. The researches show the guideline for setting any kind of standards. The impacts of the standard that is the most important section are also determined. Based on the achieved data the set standards can be accept or reject. The positive effects mean the ability of the implementing the standards.

3.2 Conduct the test cycle

One of the most important issues in order to improve the fuel economy standard for motor vehicles in Iran is the determination of the motor vehicle fuel consumption level through the testing procedure protocol. Regulatory authorities, manufacturers and consumers can continuously evaluate the energy consumption, through the test procedure. Requirements for an ideal test procedure are (Meier and Hill 1997):

- To show the actual conditions of use

- To have repeatable performance, real results
- To reflect the relative performance of design options for a particular product
- To cover many models in the category of product
- Being cheap to do
- To be easily upgraded and modified by using new technologies
- To give results which are comparable with results of other tests

However, there are many problems in fulfilling the above conditions. Mahlia *et al*. have recommended the ISO (International Organization for Standardization) test procedure with following benefits (Mahlia, Masjuki et al. 2002):

- To reduce trade barriers
- To avoid using complex technical
- To save time for developing test procedure especially for policy makers and manufacturers

However, there is no ISO test procedure for measuring the fuel economy, therefore it is impossible to use in this study. But, other recognized international standards for the development of test procedure will be considered.

Three standard procedures are internationally recognized in order to determine the fuel economy standard, which are the same as those implemented for emission standard certification. Most of these tests are chassis dynamometer test for vehicle testing. In the chassis dynamometer test, the real on-road driving pattern of a vehicle is simulated in the laboratory. In addition to chassis dynamometer test there is another method that is called engine dynamometer. In this method only a test engine is performed based on the specific load and speed conditions. The chassis dynamometer and engine dynamometer tests are used for relatively heavy vehicles (passenger cars and small trucks) and heavy duty vehicles (big trucks and busses), respectively.

Different test procedures are used to illustrate the driving conditions in different regions. Some of the characteristics of these cycles are: the traveled distance, the duration, the average speed of travel and the maximum speed of travel

One of the conditions that must be met for the cycle is the maximum speed in the cycle should not exceed the maximum allowable speed for the local roads in a country.

3.3 Fuel Economy Standards

In this study, a statistical method is used to establish fuel economy standards for motor vehicles in Iran, and an engineering/economic approach is implemented to calculate potential fuel economy improvement. Mahlia states that in order to establish efficiency standards, following conditions are necessary for any approach (Mahlia, Masjuki et al. 2002):

- The level of standard must have positive effect on the environment
- To protect the consumer against a large increase in total cost over the life of the product, before implementing the standard

The statistical analysis starts with a set of fuel economy rating (FER) for different car models on the market. One way to measure the FER of motor vehicles is, to determine the traveled distance per unit of fuel consumption (km/L) that is used in this study. In order to determine the relationship between FER and engine displacement, the regression analysis has been conducted and the trend line which is the average FER of motor vehicles is drawn. The trend line helps us to choose the motor vehicles that are better to be removed from the market (Turiel, Chan et al. 1997). For the statistical analysis, the annual total number of vehicles and the number of different vehicle models which are currently available in Iran is required.

In this study, to determine fuel economy standards, motor vehicles are placed in separated classes regards to the engine capacity. The fuel economy of motor vehicles will be analyzed, consider to these classes.

After statistical analysis, the fuel economy standard is proposed. The chosen standard level must be consistent with the percentage of fuel economy improvement per year and the average fuel economy of motor vehicles. It is essential to exist enough time in order to revise the standards set by policy makers. . There are different fuel economy standards for various engine capacities, and usually higher engine capacity gives higher fuel economy for motor vehicles. The standards are often implemented, after several years of data collection. Distribution fuel economy rating can be achieved by using the following equation:

$$FER_{STD} = \sum_{i=1}^{n} \frac{FER_i}{n} \times (1 + \%STD) \tag{3.1}$$

$$FER_i = FER_{Ysc} \times (1 + AFI_i)^{(Yse_i - Ysc)} \tag{3.2}$$

The annual fuel economy improvement (AFI) is calculated based on the average annual fuel economy rating. The average annual fuel economy is evaluated by using following equation:

$$FER_i = Ym \times \frac{Nv_i}{FC_i} \tag{3.3}$$

The equation 3.4 is used to determine the annual fuel economy improvement that is indeed the average percentage of improvement of fuel economy

$$AFI = \left(\frac{FER_i - FER_{i-1}}{FER_i} \right) \times 100 \tag{3.4}$$

In order to achieve a more efficient engine, potential improvements analysis is used. In the potential improvement analysis a part of the existing system changes or a new section is added. The engineering/economic approach can be applied for the potential improvement analysis. (Turiel, Chan et al. 1997) have proposed the following steps for the engineering / economic approach: select product classes, select baseline units, select design options for each class, calculate efficiency improvement from each design option, calculate efficiency improvements of combination design options, develop cost estimates for each design option and generate cost-efficiency curves

Another objective of engineering / economic approach is, to determine the feasibility of the proposed fuel economy standards. The standard level must be achievable with an acceptable cost impact in order to implement the standard program.

In this study, to determine fuel economy standards, motor vehicles are placed in separated classes regards to the engine capacity. The fuel economy of motor vehicles will be analyzed, consider to these classes.

The starting point for analyzing the design options for fuel economy improvement, is baseline unit. A product that has a minimum or average efficiency of existing models is often considered as a baseline model for non-standard products (Turiel, Chan et al. 1997). In order to increase the quality and competitiveness of products in Iran, the Iranian produced motor vehicles with the lowest fuel economy for each class category are selected as the baseline unit.

To improve the fuel economy value, design options are alternatives in the design of the baseline model. The design option varies for each class category according to the requirements of baseline model. Based on addition or replacement a more efficient component the potential designs options can be chosen.

The main purpose in this study is to improve the fuel economy value. To achieve to this purpose throw this analysis, the potential fuel economy improvement of motor vehicle is calculated from the implementation of individual design option. By adding improvements from the additive design to the baseline model the fuel economy value related to design options can be determined.

In this analysis, a combination of design options is used in order to calculate the potential fuel economic improvement of motor vehicle. The combination of design options are obtained from the cumulative changes in the base models. The fuel economy value can be achieved by accumulating the improvement of the design options.

In the cost estimation the expected cost for producing motor vehicle with the improved design options and manufacturing are determined. The data of estimated cost can be obtained from vehicle manufacturers. However, sometimes it is difficult to get the estimated costs data of the production from manufacturers, in this case, Turiel has stated that it might be essential to go directly to retail cost. In this study, it is assumed that the maintenance and installation of the new design options are only replacements of the same, but more efficient, components. Therefore, the cost of maintenance and installation costs are excluded from the calculations.

In order to develop the cost - efficiency curves, the life cycle cost must be calculated. To determine the present value of future energy cost savings, LCC should be calculated by using the discount rate in the year of standard promulgating. As it defined by (Turiel, Chan et al. 1997; Turiel, Atkinson et al. 2001), life cycle cost is the purchase price plus the annual operating expenses discounted over the lifespan of a particular product. The LCC can be calculated using the following equation:

$$LCC = PC + \sum_{t=1}^{N} \frac{OC_t}{(1-r)^t} \qquad (3.5)$$

Assuming that the operating costs are constant over time, Equation 3.5 can be summarized as the following equation:

$$LCC = PC + PWF \times OC \tag{3.6}$$

The present worth factor in equation 3.6 is obtained from following equation:

$$PWF = \frac{1}{r}\left[1 - \frac{1}{(1+r)^N}\right] \tag{3.7}$$

To calculate the LCC, it is necessary to determine operating cost. The operating cost can be calculated from equation 3.8 as a function of annual fuel consumption, fuel price and annual maintenance cost.

$$OC = \left(\frac{Ym \times PF}{FER}\right) + MC \tag{3.8}$$

The amount of time needed to recover the initial investment on increased efficiency through lower operating costs, is called the payback period (PAY). Equation 3.9 can be used to calculate PAY (Turiel, Chan et al. 1997):

$$PAY = -\frac{\Delta PC}{\Delta OC} \tag{3.9}$$

The ratio of added cost (from baseline model to the most efficient model) to decrease in annual operating costs is PAY. If the decreased operating cost does not cover the increased purchase price, the calculated PAY for a product will be more than its lifetime.

3.4 Fuel economy label

Energy label, is an optional or mandatory sticker that is attached to the product and contains the information about product energy consumption (Mahlia, Masjuki et al. 2002b). The energy label is implemented to make consumers aware of the fuel economy of different vehicles (Raimund and Fickl 1998).

In this study, it has been tried to design the proposed fuel economy label understandable for consumers and suitable for being reference in legislation.

Fuel economy label contains information that enables costumers compare fuel consumption of different models of motor vehicles according to specified criteria for heavy duty vehicles (from A to E). Information on labels should be legible and clear. Fuel economy labels for each class of vehicles are developed based on vehicle fuel consumption standards for each vehicle model. The proposed fuel economy label is designed based on the old common label in Iran. This label is based on fuel economy bar rating system. The rating system is divided into seven classes, the highest and lowest fuel consumption are rated A and E, respectively. Fuel economy label for motor vehicles is in term of L/100km. Also it includes the information about model of motor vehicle, capacity of engine and emission.

3.5 Impact of the fuel economy standard and label

In this section, the effects of fuel economy standards and labels on the potential fuel savings, environmental and potential economic savings based on the theory developed by (Mahlia, Masjuki et al. 2002c) are reviewed separately.

3.5.1 Impact of the fuel economy standard

In the three following parts, the effect of fuel economy standards is discussed and calculated.

3.5.1.1 Potential fuel savings

The formula for calculation of the potential fuel savings is the average annual fuel consumption of motor vehicles in Iran while the standard is applied. The motor vehicle shipment, scaling factor and shipment survival factor are some essential calculations before calculating the potential fuel savings due to standards implementation. In the following section a comprehensive explanation of each variable is presented.

A) Baseline fuel consumption

B) Baseline fuel consumption in the year of standards implementation

The fuel consumption can be predicted based on the annual fuel economy improvement for the future. Equation 3.11 can be used for this purpose.

$$BFC_S = BFC_{Ysc} \times (1 + AFI)^{(Ysc_i - Y_{SC})} \tag{3.11}$$

C) Fuel consumption standards

The fuel consumption standard is the percentage of fuel economy improvement from the baseline fuel consumption and can be calculate by following equation:

$$SFC_{MV} = BFC_S \times (1 - \eta_S) \tag{3.12}$$

D) Initial unit fuel savings

The total amount of fuel saved calculated from the difference between annual unit fuel consumption of a motor vehicle with and ones without fuel economy standards, is defined as initial unit fuel savings. The equation 3.13 presents this calculation:

$$UFS_S = BFC_S - SFC_{MV} \tag{3.13}$$

E) Shipment

Shipment data for motor vehicles can be calculated from equation 3.14:

$$Sh_i = (Nv_i - Nv_{i-1}) + Nv_{i-L} \tag{3.14}$$

F) Total fuel economy improvement

Total fuel economy improvement is equal to the percentage ratio of the initial unit fuel savings to the baseline unit fuel consumption in the year that the standards have been enacted. Total fuel economy improvement is obtained using equation 3.15:

$$TI_S = \frac{UFS_S}{BFC_S} \times 100 \tag{3.15}$$

G) Scaling factor

The scaling factor, scales down the unit fuel savings of motor vehicles to zero over the effective lifetime of the standards as well as the incremental cost. The following equation gives the scaling factor:

$$SF_i = 1 - \left(Ysh_i - Yse_i\right) \times \frac{AFI}{TI_S} \tag{3.16}$$

H) Unit fuel savings

The natural progression of expected fuel economy improvement in the baseline case is considered as a unit fuel saving. After the implementation of standards the unit fuel saving decreases using the scaling factor. The following equation can be used to calculate the fuel savings of motor vehicle

I) Shipment survival factor

The shipment survival factor can be calculated by using Equation 3.17. In cases where the standards setting is shorter than 2/3 the average lifetime of the product, shipment survival factor will be considered 100%.

$$SSF_i = 1 - \left[\frac{\left(Yse_i - Ysh_i\right) - \frac{2}{3}L}{\left(\frac{4}{3} - \frac{2}{3}\right)L} \right] \tag{3.17}$$

J) Applicable stock

The applicable stock is calculated from multiplication of shipments in particular year and the shipmen survival factor, plus the number of vehicles affected by the standard engine in the previous year.

K) Potential fuel savings

Potential fuel savings can be calculated from the following equation

$$FS_i = \sum_{i=S}^{T} AS_i \times UFS_i \times SF_i \tag{3.18}$$

Where:

AS_i = applicable stock in year *i*

UFS_i = Unit fuel savings in year *i*

FS_i = fuel savings in year *i* (liters)

SF_i = scaling factor

3.5.1.2 Potential economic savings

The potential bill savings, net savings and cumulative present value are some of the economic effects of standard that are given in the following sections for the calculation

A) Initial incremental cost

As shown in this equation the initial incremental cost is defined as the unit fuel savings multiply to incremental cost.

$$IIC_S = UFS_S \times IC \tag{3.19}$$

B) Capital recovery factor

The correlation between the lifespan of motor vehicle and the real discount rate is considered as the capital recovery factor that is shown in the equation below

Where:

$$CRF = \frac{d}{\left[1-(1+d)^{-L}\right]} \quad (3.20)$$

CRF = Capital recovery factor

d = interest rate per year (%)

L = Lifespan of motor vehicle

C) Potential bill savings

The equation 3.21 shows the calculation of the potential bill savings which is a function of the fuel savings multiplied by an average unit fuel price.

$$BS_i = FS_i \times PF_i^n \quad (3.21)$$

D) Net savings

There are two following methods for estimating economic impact.

Annualized cost

In this method the incremental cost is distributed over the lifetime of the motor vehicle and the expenditure pattern is consistent with the flow of bill savings. Also the net savings are smoothed over time. In this method, net savings can be calculated using Equation 3.22

$$ANS_i = FS_i \times PF_i^n - \sum_{i=S}^{T} AS_i \times CRF \times SF_i \times IIC \quad (3.22)$$

E) Cumulative present value

The cumulative present value that is a function of the percentage of real discount rate and the annual cost saving, is calculated using equation 3.23.

$$PV(ANS_i) = \sum_{i=S}^{T} \frac{ANS_i}{(1+d)^{(i-Ydr)}} \quad (3.23)$$

3.5.1.3 Potential environmental impact

By implementing the fuel economy standards, emissions from motor vehicles including CO_2, SO_2 and NO_x are reduced as result of fuel saving. Environmental impacts resulted from the implementation of fuel economy standards can be calculated using following equation:

$$ER_i = FS_i \times (Em_1 + Em_2 + Em_3 + ... + Em_n) \quad (3.24)$$

3.5.2 Impact of the fuel economy label

The same as fuel economy standards, the fuel economy label impacts on the fuel saving and economic saving. Also it has positive effect on the environment. These impacts are discussed here.

3.5.2.1 Potential fuel savings (label)

To calculate the potential fuel savings through the implementation of fuel economy label, the Mahlia's theory has been used (Mahlia, Masjuki et al. 2002).

A) Baseline fuel consumption

In this study, it is assumed that the fuel economy label program is implemented at the same time with the fuel economy standards. Therefore, the baseline fuel consumption for fuel economy label is the same as baseline fuel consumption for fuel economy standard.

B) Label fuel consumption

The labels fuel consumption can be calculated as a function of fuel economy standards using following equation.

$$LFC_{MV} = SFC_{MV} \times (1 - \eta_l) \quad (3.25)$$

C) Initial unit fuel savings

The equation 3.18 presents the calculation of unit fuel savings which is the difference between the baseline fuel consumption and the label fuel consumption.

D) Shipment survival factor

By using equation 3.19 the shipment survival factor can be calculated. It is a function of the retirement function and the annual retirement rate.

E) Applicable stock

The applicable stock is the shipments in particular year plus the number of motor vehicles affected by standards in the previous year multiplied by the shipment survival factor. The applicable stock can be calculated using equation 3.20.

F) Potential fuel savings

According to the equation 3.21, the total fuel savings can be calculated as a function of the applicable cost, unit fuel savings and the scaling factor.

3.5.2.2 Potential economic savings (label)

The net savings, the potential bill savings and the cumulative present value are the economic impacts of the fuel economy label implementation. The explanation of each variable is presented in the following sections.

A) Initial incremental cost

The equation 3.22 expresses the initial incremental cost per unit of motor vehicle which is calculated by the unit fuel savings multiplied with the incremental cost.

B) Capital recovery factor

The equation 3.23 shows the calculation of capital recovery factor. It is the function of the lifespan of the motor vehicle and the real discount rate.

C) Bill savings

The bill savings is defined by the fuel savings multiplied by an average unit fuel price, which has been presented in equation 3.24.

D) Net savings

The same as standards there are two methods for determining economical impact of fuel economy label. These ways are cash flow and annualized costs which are expressed in the equation 3.24 and 3.25 respectively.

E) Cumulative present value

The equation 3.23 expresses the cumulative present value of annualized net savings. It is a function of the percentage of real discount rate and annual cost savings.

3.5.2.3 Potential environmental impact (label)

The carbon dioxide (CO_2), nitrogen oxide (NO_X), carbon monoxide (CO) and sulfur dioxide (SO_2) emissions have the most negative impacts to the environment which are produced by motor vehicles. The environmental impact due to the fuel economy label implementation is calculated base on the fuel savings. The equation 3.24 expresses the potential impact of the fuel economy label on the environment.

3.6 Prediction of market transformation

For indicating the shift of the present average fuel economy towards the efficiency when the fuel economy standards and label programs are enacted it is necessary to predict the market changes. The bell curve is used to represent this transformation, in this research.

The average fuel economy of the motor vehicles from the first curve (present fuel economy) is pushed to the second curve (standards fuel economy) by executing the fuel economy standard plan. Figure 3.1 shows the expected change of fuel economy of heavy duty vehicles in the market due to this program.

In addition, it is supposed to be purchased more fuel economic vehicles by costumers by implementation of fuel economy label. The fuel economy label forced the average efficiency of the vehicles towards more efficient vehicles in the year of standard implemented. Therefore, as it can be seen in figure 3.1, the market changes will push the average fuel economy from the second curve to the third curve.

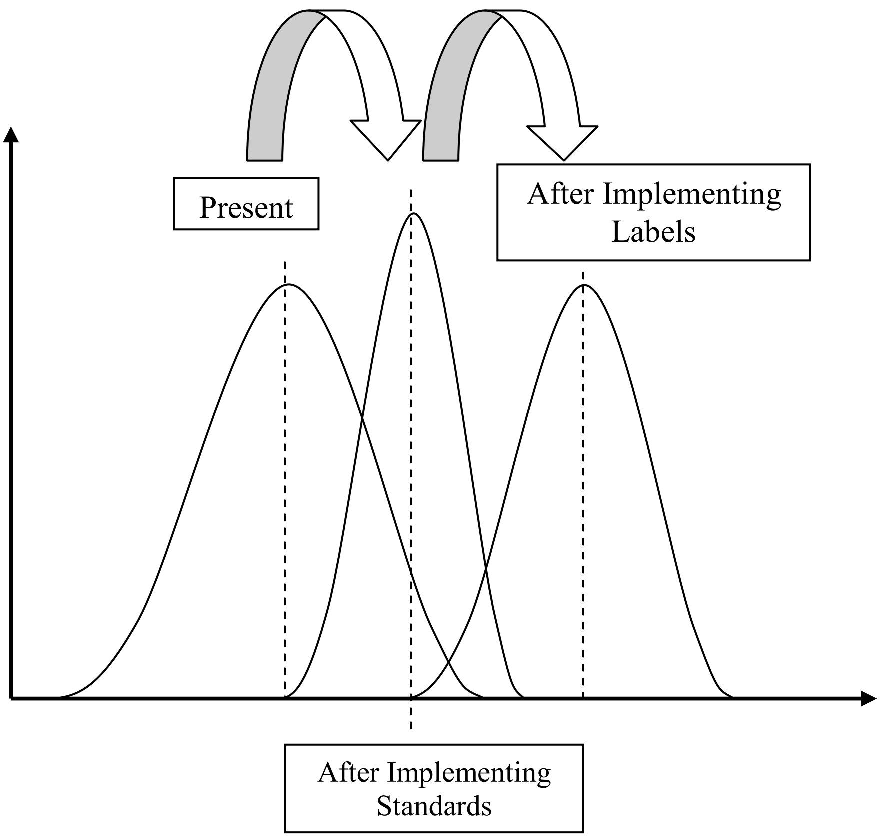

Fig. 3.1.Market transformations due to standards and labels implementation

The present average fuel economy rating, standards average fuel economy rating and labels average fuel economy rating are three steps which cause the market transformation. According to the figure 3.1 the curves represent the unit distribution of motor vehicles before and after the implementation of fuel economy plan. According to the first curve the average fuel economy is increased (without standards) to second curve (with standards) and after execution of fuel economy label program the fuel economy is increased to the third curve. In the following section these three steps are discussed:

1. Present average fuel economy rating

   The average motor vehicles fuel economy rating in the market before the standards and labels are implemented is considered as present average fuel economy rating. The equation 3.26 calculates the present average fuel economy rating which base on the market survey data:

$$FER_{PAF} = \frac{1}{n}\sum_{i=1}^{n} FER_{Ysc} \times \left(1 + AFI_i\right)^{\left(Yse_i - Ysc\right)} \tag{3.26}$$

2. Standards average fuel economy rating

   The equation 3.27 present the calculation of the standards average fuel economy rating, which is the average FER distribution of motor vehicles in the year of implementation of standards program.

$$FER_{SAF} = \frac{1}{n}\sum_{i=1}^{n} FER_{STD} \tag{3.27}$$

3. Labels average fuel economy rating

   The label average fuel economy rating is the average FER distribution of motor vehicles when the labels program is executed. The bar type labels are graded from the highest efficient (Grade A) to the least amount (Grade E). In this type of labels the bar C is determined in middle of interval, and it is assumed as standard. Therefore, the label average fuel economy rating for bar type labels can be calculated by using the equation 3.38:

$$FER_{LAF} = FER_{LMF}(1+\delta\%) \qquad (3.28)$$

CHAPTER 4
RESULTS AND DISCUSSIONS

4.1 Introduction

In this section we are going to talk about outcomes of the following items in Iran these items are: fuel economy standards, fuel economy label, test procedure, market changes and the effect of fuel economy standards and labels on petroleum utilization of heavy duty vehicles in transportation, on the nationwide economy and also on the environment. The statistical analysis is used to develop the fuel economy standards. And the engineering/economic approach is also carried out to scrutinize potential fuel economy development of countrywide motor vehicles in transportation. Fuel economy label is distorted from that improved by the power commissions for applicants in Iran to demonstrate motor vehicles fuel economy and in addition other appropriate details. The fuel economy comprehensive bar ranking is improved in order to classify each motor vehicles in its classes in a bar type developed fuel economy label. In this section, the changes of market due to implementing the fuel economy standards and labels are also discussed. Lastly the effect of the execution of the fuel economy standards and labels on fuel economy and environment are represented.

4.2 Data collection

With quickly rising quantity of motor vehicles in this country the instance has approach to implement fuel economy standards and labels for motor vehicles to restrain the inefficient vehicles which consumes excessive fuel. The test procedure is the fundamental of this program. The concentrated data collection and evaluation is necessary for setting a test procedure. In this section, the needed data for standards and labels and test procedure and also information for the impact calculation are discussed.

4.2.1 Fuel Economy Standards

To facilitate establishing of fuel economy standards for motor vehicles in Iran a considerable quantity of information are required. Information such as the producer, car year, model, engine capacity and fuel economy rating of available cars in Iran are gathered. The major collection method is used to attain necessary information is using the published books and brochures by the manufacturers and optimization fuel consumption and transportation organization. The information that can be comparable, are only used to achieve accuracy and relevancy. The information for a total of 127 models of diesel motor which are available in Iran is gathered.

Table 4.1.Motor vehicle fuel consumption and unit of vehicles

Year	No. Vehicle	Consumption (million lit)
1998	3,049,048	10,320
1999	3,235,959	11,211
2000	3,444,226	11,649
2001	3,699,883	12,688
2002	4,009,528	13,575
2003	4,527,423	14,899
2004	5,217,202	16,466
2005	6,069,208	17,731
2006	6,964,421	19,585
2007	7,880,001	21,468
2008	8,726,500	18,841

A number of other major information inputs are essential for the study. Nevertheless, the same as other developing countries achieving complete technical and statistical information seems impossible. In order to have ample time for planning and consequently implementing the standards program, the year the standards should be enacted is set at 2013. The calculation for the baseline fuel consumption is according to the predicted data of Table 4.1 and standards fuel consumption is a 5% improvement from the baseline fuel consumption (refer section 4.4.1.2). The calculation for the baseline fuel consumption and the standards fuel consumption. The annual fuel economy improvement is calculated by utilizing equation 3.3 and equation 3.4 according to the considered predicted data of Table 4.1. The descent of the yearly fuel economy improvement. Table 4.2 represent these results.

Table 4.2.Results of motor vehicles survey data

Description	Values
Year standards enacted	2013
Discount rate	7%
Life span	10 years
Baseline fuel consumption	3649.6 lit/year
Estimated fuel price in year of implementation	2000 Rials (0.5 RM)
Standards fuel consumption	3517.12 lit/year
Annual mileage	20000 km

4.2.2 Fuel economy label

The information gathered from the Energy Commissions of Iran used for the fuel economy label. The label developed by the Energy Commissions is for exploit of appliances in this country. This label will be modified and utilized as the fuel economy label for heavy duty vehicles. This is because Iranian customers would be accustomed with the label in advance and would not be confused to recognize different kinds of labels. Because the fuel economy label commenced to be utilized is a bar type label, information are essential to develop the fuel economy bar rankings. This 7 bar rankings system is to determine the FER for each bar. The information is essential for the FER for motor vehicles in each class group and this is gathered via transportation data book of Iran.

4.2.3 Impact of standards and labels

The effect of the fuel economy standard and the fuel economy label is considered independently and the outcomes also are shown in combination. The impact includes environment, fuel consumption, and economy. The technique for information gathering is utilizing the information published by the manufacturers and government organizations. The statistics that are shown in table 4.3 are the essential information to calculate the effect of the standards and labels (Emission 2002).

Table 4.3.Input data for potential environment impact

Description	Value
CO_2 emission	2.4 (kg/lit)
SO_2 emission	0.074 (g/lit)
NO_X emission	44.76 (g/lit)
CO	114.5 (g/lit)

4.3 Selected Test Procedure

At the time of selecting to implement an internationally known testing cycle its applicability of real situation is the major concern. Because of that the velocities used in the examination cycle should not go beyond the speed limit set for local roads.

4.4 Fuel economy standards

The steps for determining the fuel economy standards for motor vehicles are presented in following sections. The fuel economy standards chosen will be according to information gathered as stated in the previous parts.

4.4.1 Statistical analysis

The statistical analysis is performed according to market study of motor vehicles. The essential statistics are existing characteristics of motor vehicles in the existing market specifically the number of automobiles and its consequent fuel consumption. By recognizing the motor vehicles accessible at a definite time in the market this analysis is carried out and to find out the reliance of fuel consumption with respect to the engine capacity a regression analysis is executed. After verifying the regression line, the least fuel efficient automobile model that is below the regression line will be removed from the market.

4.4.1.1 Motor vehicle class category

The beginning of statistical analysis is with categorization of motor vehicles in different classes which special fuel economy standards might be appropriate for each one. For motor vehicles the classes are typically determined base on their engine capacity. The proposed class category is chosen according to the existing structure utilized by the Road Transport Department of Malaysia for road tax payments. This class category is chosen due to its accessibility and familiarity to car owners.

4.4.1.2 Fuel economy standards development

The classification of the fuel economy standards for motor vehicles is regarded to its engine capacity. As a general rule, a car with a high engine capacity would regularly has a lower number of fuel economies. This means that the fuel consumption of car would be more liters for a definite length of distance compared to a car with a lower engine capacity. So, standards will be lower for the higher engine capacity.

The standard is planned to be set according to the FER for heavy duty vehicles. The standard is regularly 5%, 10% or yet 20% over the indication line (Mahlia, Masjuki et al. 2002a; Mahlia, Masjuki et al. 2005). Planning an attainable standard is vital for local producers' endurance. Hence the standard is planned at a lowest amount 5% more fuel economic than the market average.

4.4.2 Engineering/economic analysis

The reason of implementing the engineering/economic analysis is to study in detail the enhancement that can take place in order to increase the fuel economy of automobiles that do not reach the planned minimum of fuel economy standards. The determination of classes of cars is the initial move. After that the baseline unit has to be launched. The baseline unit is the beginning point for analyzing the design options, both independently and when combined, for improving fuel economy. The least fuel economic model found from the market search is selected as baseline unit for analysis. Later by calculating the life cycle cost and payback period by identifying the incremental cost for each design option this analysis is made stronger. In the following sections, each step stated in the methodology section is discussed further.

4.4.2.1 Selection of motor vehicle class

The initial move in the engineering/economic study is classification of the motor vehicles into different class categories. In the previous segment discussion has been made about the classes.

4.4.2.2 Selection of baseline units

The initial point for analyzing design options for improving the fuel economy of motor vehicles is a baseline unit. The baseline model chosen is the least efficient model for products without standards, (Turiel, 1997). The chosen baseline models are products of local manufacturers. The baseline models are determined from the research information.

4.4.2.3 Selection of design options for each class

The alternatives in the design of the baseline motor vehicle are model design options in order to improve the fuel economy. Choosing the appropriate design option will perceive possible enhancement in which a part of a preexisting structure is modified or a new part is added in order to gratify a new basic necessity that is a higher efficiency compared to the current model. Existing motor vehicles such as in the United States implemented some of the options. The potential enhanced design options are identified according to the options that give a high fuel economy improvement with a low price raise and appropriate when the options are combined. Table 4.4 presents the list of possible design options for choosing (Bezdek and Wendling 2005).

Table 4.4. Potential design options improvement for each class

NO	Technology	Potential Fuel Efficiency Improvement (%)	Potential Average Retail Price Increase (RM)
A	**Engine technologies production intent engine technologies**		
A1	Engine friction and other mechanical/hydrodynamic loss reduction	1-5	133-532
A2	Application of advance low friction lubricants	1	30-42
A3	Multi-valve, overhead camshaft valve trains	2-5	399-532
A4	A4 Variable valve timing 2-3 133-532	2-3	133-532
A5	Variable valve lift and timing	1-2	266-798
A6	Cylinder deactivation	5-7	426-958
A7	Engine accessory improvements	5-10	319-426
A8	Engine downsizing and supercharging	2-6	1330-2128
B	**Emerging engine technologies**		
B1	Variable compression ratio	2-6	798-1862
C	**Transmission technologies Production-intent transmission technologies**		
C1	Continuous variable transmission (CVT)	4-8	532-1330
C2	Five speed automatic transmission	2 3	266-585
D	**Emerging transmission technologies**		
D1	Automatic shift/manual transmission	3-5	266-1064
D2	Advanced continuously variable transmission	0 2	1330-3192
D3	Automatic transmission with aggressive shift logic	1-3	0-266
D4	Six-speed automatic transmission	1-2	532-1064
E	**Vehicle technologies Production-intent vehicle technologies**		
E1	Aerodynamic drag reduction on vehicle design	1-2	0-532
E2	Improved rolling resistance	1-1.5	53-213
F	**Emerging vehicle technologies**		
F1	42V electrical system	1-2	266-1064
F2	Integrated starter/generator (idle off restart)	4-7	798-1330
F3	Electric power steering	1.5-2.5	399-570
F4	Vehicle weight reduction (5%)	3-4	798-1330

4.4.2.4 Fuel economy improvement for each design option

The fuel economy improvement is calculated according to each design option chosen. This method is organized individually the potential fuel economy improvement for each of the design alternative. The design options are determined according to precedence of the highest FER improvement and the lowest incremental price. The incremental price is the cost raise to manufacture the motor vehicles with the new design option.

4.4.2.5 Fuel economy improvement for combination design option

The beginning of the fuel economy improvement for the combination design options from the baseline unit and then the accumulation of the design changes together with the design FER improvement take place. The incremental prices for the design options are calculated collectively. The design options are determined according to precedence of the highest FER improvement and the lowest incremental cost.

4.4.2.6 Cost estimates for each design option and cost-efficiency curves

The life-cycle costs (LCC) detain the transaction between buying cost and operating cost for motor vehicles. The LCC in this analysis can be computed using equations 3.5 and the input information from the prior segment. The payback period measures the quantity of time it takes consumers to recover the assumed higher buying costs of the improved fuel economic motor vehicles through lower operating expenses. The equation 3.9 is used to calculate the payback period. A number of input values like fuel price, discount rate, average mileage use and automobile lifespan are necessary.

4.4.3 Expected market transformation due to standards

Inefficient automobiles will be removed from the marketplace and consequently a market change will take place in Iran by implementing in fuel economy standards. The two curves which describe the market condition before and after the year of fuel economy standards execution can be considered. In the marketplace change analysis at the time that the fuel economy standards and labels plan is executed, it is expected that the current average fuel economy will move from 291 gr/kWh to the standard average fuel economy of 289 gr/kWh when the fuel economy standards program is executed. And this average will later move to the label average fuel economy of 273 gr/kWh according to the execution of the fuel economy label.

The standards average FER is computed utilizing the data gathered but with all the motor vehicles not attaining the standards eliminated from the list. The automobile fuel economy is forced to change from first curve to the second curve buy the marketplace transformation. Equations 3.27 and 3.28 have been used to calculate the marketplace transformation and the product distribution due to compulsory fuel economy standards.

4.5 Fuel economy label

The execution of Fuel economy standards and labels are usually as a pair. Standards are more in the direction of the technological implementing of fuel economy despite the labels causes costumers to choose a more fuel economic automobile throughout visual evaluation. Through, one thing competition will be generated among producers, and that is heavy customers concerning the effectiveness of the fuel economy label. By setting up suitable fuel economy labels, vehicles with the greatest fuel economy have higher chance to be traded in large quantity.

This will indirectly encourage automobile producers to develop their manufactured products while taking care of their production cost to be at the minimum level in order to win over the market. What is shown in the following part is the result of the fuel economy label selection.

4.5.1 Proposed fuel economy label

The proposed fuel economy label as developed by the Energy Commissions for appliances sold in Iran will remain unchanged. This is attributable to the fact that consumers will already get use to the proposed label and will not need to spend additional time putting effort to be aware of the new label. The label will nevertheless be appropriate for the requirements of automobile. Figure 4.1 shows the fuel energy label proposed to be used in Iran.

A few adjustments due to the wording suited for automobiles are applied but the type and size of the font is still remain. During the time that car is in exhibition it must be attached and visible in the upper right corner of the front windshield of the car so that the customer at the time of making the decision to buy will get the information.

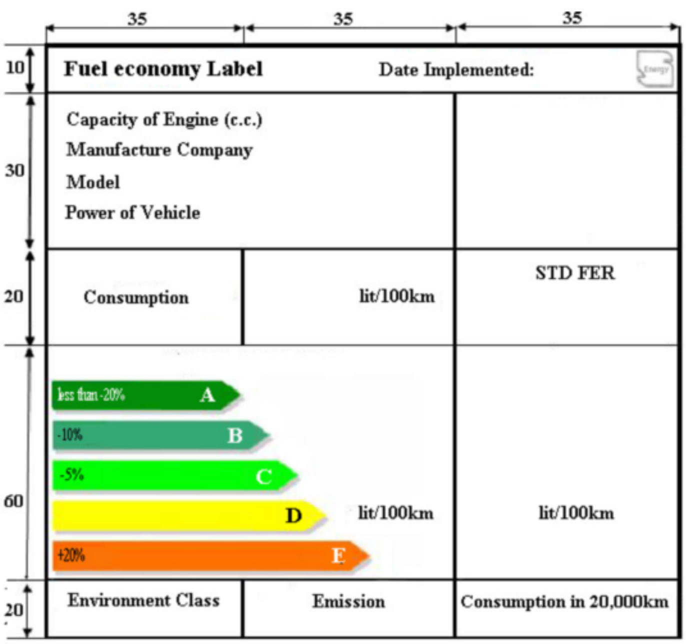

Fig. 4.1.Proposed fuel economy label

4.5.2 Fuel economy bar ratings

In this paper, the determination of fuel economy bar ratings is based on the distributions of fuel consumption of cars consistent with each class category of automobiles. Each class category of automobiles will have different series of fuel economy bar rating to hold to as each class signifies an individual engine size of cars. The determination of fuel economy bar ratings takes place after the enactment of fuel economy standards.

The bar type labels are graded from the highest efficient (Grade A) to the least amount (Grade G). In this type of labels the bar D is determined in middle of interval, and it is assumed as standard. The standard is proposed to be performed in the year 2013 as a result from the computation.

Table 4.5.The standards FER for each class

Grade	Range
A	FER < 6% less than STD FER
B	6% less than STD FER < FER < 2% less than STD FER
C	2% less than STD FER < FER < 2% more than STD FER
D	2% less than STD FER < FER < 6% more than STD FER
E	6% more than STD FER < FER < 10% more than STD FER

Table 4.6.The class for heavy duty vehicles

Class	DEC1	DEC2	DEC3	DEC4	DEC5
Displacement Volume (lit)	$2 \leq V < 4$	$4 \leq V < 6$	$6 \leq V < 8$	$8 \leq V < 12$	$12 \leq V < 16$

Table 4.5.The standards for heavy duty vehicles gr/kWh

CLASS	Class 1	Class 2	Class 3	Class 4	Class 5
STD	244.2	232.1	223.3	217.8	209

4.5.3 Expected market transformation due to fuel economy labels

What will encourage manufacturers to produce more fuel economic motor vehicles is introducing fuel economy labels combined with standards that will also cause change in the market.

The method of predicting marketplace changes has been explained in Chapter 3 section 3.6. According to the labels it is predicted that consumers will buy cars that are more fuel economic and therefore cars with high fuel consumption will slowly be omitted from the market. The three curves characterize the unit distributions of cars in the market according to FER, before and after of the execution of fuel economy labels. The marketplace transformation pushing the cars FER from the first curve towards the second curve according to standards, while labels progressively pull the market by improving the fuel economy of cars to at least FER. The equation 3.28 is used to calculate the label average FER.

4.6 Impact of the fuel economy standards and labels

The influence on fuel, the influence on Iran's economy and also the influence on the environment are three major predicted effects of the fuel economy standards and labels. The impacts of the standards are independently calculated at the first step. These impacts are then computed collectively with the labels using equation (3.19) and (3.20). The impacts of the fuel economy standards and labels are correspondingly calculated in the subsequent parts.

4.6.1 Impact of the fuel economy standards

In this section we are going to predict the impact of the fuel economy standard on fuel, economy and environment. To help this calculation some necessary information is needed. This information consist of: number of cars influenced by standards, appliance shipment, shipment survival factor, scaling factor and average motor vehicle fuel consumption in Iran. Tables 4.6 and 4.7 represent the calculation results.

Table 4.6.Calculation results of fuel and economical impact of standards

Year	Sh	As	SF	UFS	FS	BS(Rial)	ANS(Rial)	PV(Rial)
2013	6,122,888	6,122,888	1.00	132.5	8.11E+08	5.68E+12	5.11E+12	3.18E+12
2014	6,919,873	13,042,761	0.80	106.0	1.11E+09	7.74E+12	6.77E+12	3.94E+12
2015	7,879,085	20,921,846	0.60	79.5	9.98E+08	6.99E+12	5.82E+12	3.17E+12
2016	8,881,504	29,803,350	0.41	54.3	6.64E+08	4.65E+12	3.51E+12	1.79E+12
2017	9,904,290	39,707,640	0.21	27.8	2.32E+08	1.62E+12	8.51E+11	4.04E+11
2018	10,857,995	50,565,635	0.01	1.3	6.70E+05	2.69E+09	3.08E+05	2.14E+05

Table 4.7.Motor vehicle fuel consumption with and without standards

Year	Consumption (liters)	Consumption Standard (liters)	Fuel Saving (liters)
2013	26,299,305,000	25,488,144,560	411,160,440
2014	27,403,300,800	26,297,274,667	506,026,133
2015	28,508,180,200	27,510,208,146	497,972,054
2016	29,613,943,200	28,950,125,735	3663,817,465
2017	30,720,589,800	30,488,568,133	132,021,667
2018	31,828,120,000	31,827,450,005	339,995

Table 4.6 presents the outcomes for the computation of potential fuel savings due to the execution of a heavy duty vehicle fuel economy standard in Iran. It must be concentrate on the point that the fuel economy standards for automobiles in Iran are only efficient up to a definite point in time. This is because of the AFI expected to persistently improve over time in line with the technological improvements of motor vehicles. It still improves at an average of 4.18% every year even without presence of standards. The improvement is due to technological progresses of automobiles that make it more fuel efficient over the years presents the evaluation of fuel consumption without standards (BAU) and fuel consumption with standard.

According to that it is noted that between the years of execution of the standards between 2013 and 2018 estimated quantity of 3,811,667,755 liter or about 3.8 billion-liters of fuel can be saved. And that outcome is only the minimum quantity which can be saved for the calculations of this result is only based on the minimum standards permitted. In real world there would be many cars sold that goes beyond the set standard.

The outcome of the projected economic analysis is shown. The standards execution is expected to result in the bill savings of 26.68×10^3 billion Rials annualized net dollar savings is 22.07×10^3 billion Rials and cumulative present value on annualized net savings is about 12.48×10^3 billion Rials after 5 years of execution. This research provides evidence that by introducing fuel economy standards for heavy duty vehicles in Iran, significant fuel and economic savings that will be terrifically benefit for the country will come as the result of this plan.

There will be high chance of reduction of emissions which all have negative effect on the environment such as carbon dioxide (CO_2), nitrogen oxide (NO_X) sulfur dioxide (SO_2) and also carbon monoxide (CO) which all has negative effect on the environment by executing the fuel economy label. It is also the function of the energy savings. The environmental effect of the standards is considered and the table 4.8 represent the calculated results.

Table 4.8.The emissions reduction due to program

Year	CO_2(ton)	SO_2(kg)	NO_X(kg)	CO(kg)
2013	946,785	10,026	36,307, 41	87,877,870
2014	2,64,463	81846	49,05,730	121,639,992
2015	2,95,133	7,850	4,669,229	14,267,800
2016	1,53,162	9,122	2,712,470	76, 07,100
2017	56,852	17,70	1,385,290	26,56,481
2018	1,08	50	19,989	76, 14

According to the table and figure above it can be seen that CO_2, NO_X, CO and SO_2 reductions will be about 9.14 million tons, 170 million kg, 436 million kg and 282,063 kg respectively.

4.6.2 Impact of the fuel economy label

Characteristically the impact of the fuel economy label takes place over a longer period compared to standards. Nevertheless, the research only put the impact of the fuel economy label for the effective period of the fuel economy standard under examination. The difference between standard and label impact computation is the scaling factor is not appropriate when calculating potential label impact. The reason is that the fuel economy standard which is a baseline of the label is static. Table 4.9 and 4.10 represent the result of calculations.

Table 4.9.Calculation results of fuel and economical impact of labels

Table 4.10.Motor vehicle fuel consumption with and without labels

Year	Sh	Ac	UFS	FS	BS(Rial)	ANS(Rial)	PV(Rial)
2013	6,122,888	6,122,888	132.48	8.112E+08	5.678E+12	5.110E+12	3.182E+12
2014	6,919,873	13,042,761	132.48	1.728E+09	1.210E+13	1.089E+13	6.336E+12
2015	7,879,085	20,921,846	132.48	2.772E+09	1.940E+13	1.746E+13	9.498E+12
2016	8,881,504	29,803,350	132.48	3.948E+09	2.764E+13	2.487E+13	1.264E+13
2017	9,904,290	39,707,640	132.48	5.260E+09	3.682E+13	3.314E+13	1.575E+13
2018	10,857,995	50,565,635	132.48	6.699E+09	4.689E+13	4.220E+13	1.874E+13

Year	Consumption (liters)	Consumption Standard (liters)	Fuel Saving (liters)
2013	26,299,305,000	25,488,144,560	811,160,440
2014	27,403,300,800	25,675,395,823	1,727,904,977
2015	28,508,180,200	25,736,454,042	2,771,726,158
2016	29,613,943,200	25,665,595,392	3,948,347,808
2017	30,720,589,800	25,460,121,653	5,260,468,147
2018	31,828,120,000	25,129,184,675	6,698,935,325

The above tables present that the fuel economy labels program for heavy duty vehicles implemented in 2013, by the end of the year 2018 will have a saving of about 20.1 billion liters of fuel. Due to the standards as a baseline, the economical impact of the label is calculated. The calculated results are total amount of bill savings; sum of net savings in terms of actual cash flow, sum of yearly net dollar savings and total present value using a 7% discount rate.

Implementation of The fuel economy label is expected to come up with the bill savings of 141.103×10^3 billion Rials, yearly net dollar savings is 126.993×10^3 billion Rials and cumulative present value on yearly net savings is about 62.837×10^3 billion Rials after 5 years of execution.

Just the same as standards the environmental effect of the fuel economy label is the decrease of CO_2, SO_2, NO_X and CO. A function of fuel savings is also the environmental impact. The environmental impact is considered according to information given in table 4.3. Table 4.11 present the results.

Table 4.11.The calculation results of potential environmental savings due to fuel economy labels

Year	CO2(ton)	SO2(kg)	NOx(kg)	CO(kg)
2013	1,849,446	57,025	34,492,164	88,233,977
2014	3,939,625	121,472	73,473,997	187,952,919
2015	6,319,537	194,852	117,859,374	301,494,601
2016	9,002,236	277,569	167,891,695	429,481,659
2017	11,993,871	369,811	223,685,692	572,207,590
2018	15,273,577	470,935	284,852,211	728,676,904

According to the table and figure above it can be seen that the total reductions of CO_2, NO_X, CO and SO_2 are about 48 million tons, 0.9 billion kg, 2.31 billion kg and 1.49 million kg respectively.

4.6.3 Impact of the fuel economy standard and label in combination

The combination of the fuel economy standard and fuel economy label impact is a summation of the potential saving when executed in together. Table 4.12 present the comparison of the fuel consumption with and without fuel economy standard and label and also its potential savings.

Table 4.12.Motor vehicle fuel consumption with and without standards and labels

Year	Motor vehicle fuel consumption (liters)	Motor vehicle fuel consumption with standards and labels (liters)	Fuel savings (liters)
2013	26,299,305,000	25,528,702,582	770,602,418
2014	27,403,300,800	25,761,790,590	1,641,510,210
2015	28,508,180,200	25,875,039,578	2,633,140,622
2016	29,613,943,200	25,863,011,683	3,750,931,517
2017	30,720,589,800	25,723,143,595	4,997,446,205
2018	31,828,120,000	25,464,129,576	6,363,990,424

According to table 4.12, the fuel saving by implementing the fuel economy standard and label for heavy duty vehicles in 2013 will be about 18,330,605,291 liters at the end of the year 2018. The combination of the standards and labels economic effect is a summation of annualized dollar savings, bill savings, and cumulative present value of the standards and labels for each year. Table 4.13 represents the results of these calculations.

Table 4.13.Calculation results of economic impact due to standards and labels

Year	BS (Rials)	ANS (Rials)	PV (Rials)
2013	5.3942E+12	4.8548E+12	3.0233E+12
2014	1.1491E+13	1.0342E+13	6.0189E+12
2015	1.8432E+13	1.6589E+13	9.0232E+12
2016	2.6257E+13	2.3631E+13	1.2013E+13
2017	3.4982E+13	3.1484E+13	1.4958E+13
2018	4.4548E+13	4.0093E+13	1.7802E+13

Summation of the potential reduction of CO_2, SO_2, NO_X and CO individually is the environmental impact of the fuel economy standard and fuel economy label in combination. Table 4.14 represents the environmental result.

Table 4.14.Calculation results of the environmental impact due to standards and labels

Year	CO2(ton)	SO2(kg)	NOx(kg)	CO(kg)
2013	3,796,231	117,050	70,799,706	181,111,847
2014	6,594,087	203,318	122,979,727	314,592,911
2015	8,714,670	268,702	162,528,603	415,762,401
2016	10,595,398	326,691	197,604,164	505,488,759
2017	12,550,723	386,981	234,070,982	598,774,071
2018	15,275,185	470,985	284,882,200	728,753,618

As a result, the total CO_2 reduction will be around 57,526,294 tons, while the total SO_2 reduction is about 1,273,727 kg in the same period and the total NO_X and CO reduction is about 682,865,382 kg and 1,744,483,608 kg correspondingly. Table 4.15 represents the overall potential savings from fuel economy standard and label.

Table 4.15.Overall potential savings from fuel economy standards and labels

Items	Standards	Label	Savings
FS(Lit)	3,810,997,760	14,519,607,531	18,330,605,291
BS(Rial)	26,681,674,281,840	141,103,349,777,690	167,785,024,059,531
CO_2(ton)	9,148,003	48,378,291	57,526,294
SO_2(kg)	282,063	1,491,664	1,773,727
NO_X(kg)	170,610,249	902,255,134	1,072,865,382
CO(kg)	436,435,958	2,308,047,650	2,744,483,608

Great benefits for the country's economy, customers and the environment as well as fuel reserves are easily possible by introducing minimum fuel economy standards and fuel economy label for motor vehicles. Although the customers will need to pay a higher purchase price for cars but will pay less for fuel. According to the every year improvement of fuel economy at about 4.18% per year without standards because of the technological advancements the fuel economy standards are effective for a certain period of years. The bar rating for the fuel economy label is also certain only for a definite time period. For that reason after a definite period, most of the cars will reach a maximum grade of the label and therefore the label will not be effective anymore. As a result, the fuel economy standard and label plan must be renewed and adjusted after certain period of time for remaining effective.

CHAPTER 5
CONCLUSION & RECOMMENDATION

The chosen test procedure for heavy duty vehicles makes a guideline available to calculate the fuel consumption. It is anticipated that the test procedure will be the fundamental of calculating the fuel economy for the execution of the fuel economy standard and label plan.

The standard executed in this research is assumed to be improved 5% from the average fuel economy rating baseline obtained from statistical analysis. This consideration of standards improvement is as it has been confirmed in the cost-efficiency analysis that the baseline unit of each class could be improved between about 12-18%. This means that it is probable to conquer the anticipated 5% standard improvement by using existing technologies.

In the marketplace change analysis at the time that the fuel economy standards and labels plan is executed, it is expected that the current average fuel economy will move from 291 gr/kWh to the standard average fuel economy of 289 gr/kWh when the fuel economy standards program is executed. And this average will later move to the label average fuel economy of 273 gr/kWh according to the execution of the fuel economy label.

It is aimed to implement the fuel economy standard and label in the year 2013 and it is probable to save about 18,330,605,291 liters of fuel at the end of 2018. This associates to about 167,785 billion Rials in bill savings.

The fuel economy standard and label program will also aid to decrease greenhouse gas emissions. Approximately 27,526,294tons of CO_2, 672,865,382kg of NO_X, 1,744,483,608kg of CO and 773,727kg of SO_2 could be decreased.

The effectiveness of the fuel economy standard and label program is only until the end of year 2018. To ensure the effect of this program, it should be amended after the year 2018.

For the execution of this plan the accurate information must be collected. For this reason the government must set up a framework to constantly gather information from vehicle producers and traders selling their cars in the Iranian market.

The key to the accomplishment of the fuel economy standard and label plan are consumers. For that reason a widespread quantity of data campaign should be carried out to get the message to consumers. When the fuel economy standard and label have been executed, it is essential to estimate its impact. The estimating is important to recognize the areas of weakness in the plan design and execution so that these can be made stronger.

The government is responsible for executing the fuel economy standard and label program for motor vehicles. Also cooperation with related organizations such as the Energy Commissions and cars producers themselves are vital to make sure the accomplishment of the plan.

One of the key steps in the accomplishment of the fuel economy standard and label plan is establishing an independent laboratory for testing. The facility should contain ways to predict cars maintenance, traffic behavior and the type of roads in Iran.

APPENDIX A: RELATED PUBLICATIONS

1. Mohammadnejad, M., M. Ghazvini, et al. (2011). "A review on energy scenario and sustainable energy in Iran." Renewable and Sustainable Energy Reviews.

REFERENCES

ACEEE (2011). *American council for an Energy Efficient economy*.

Agency, U. S. E. P. (2008). *Homepage of the U.S. Environmental Protection Agency*. Retrieved 2011 from http://www.epa.gov

Alberta (2007). Alberta Energy Energy measurements.

An, F. and A. Sauer (2004). Comparison of passenger vehicle fuel economy and greenhouse gas emission standards around the world. *Pew Center on Global Climate Change*, Arlington.

Bezdek, R. H. and R. M. Wendling (2005). Potential long-term impacts of changes in US vehicle fuel efficiency standards. *Energy Policy,* 33(3): 407-419.

Clerides, S. and T. Zachariadis (2008). The effect of standards and fuel prices on automobile fuel economy: An international analysis. *Energy Economics*, 30(5): 2657-2672.

Dargay, J. and D. Gately (1999). Income's effect on car and vehicle ownership, worldwide: 1960-2015. *Transportation Research Part A: Policy and Practice*, 33(2): 101-138.

W., Heritage and the Arts (2008). Fuel consumption label. *Department of the Environment*. Australia.

DieselNet (2007a). DieselNet (2007a) Emmision test cycles: Japanese JC08 Cycle.

DieselNet (2007b). DieselNet (2007b) Emmision test cycles: Japanese 10-15 mode.

Du Pont, P. T. (1998). Energy policy and consumer reality: the role of energy in the purchase of household appliances in the US and Thailand, *University of Delaware*.

Egan, K. (1998). Building national standards regimes: regulatory and voluntary approaches in the Philippines and Thailand. *Compendium of Energy Conservation Legislation in Countries of the Asia and Pacific Region*. United Nations, New York.

Emission (2002). Emission Factors Emission factors for transport.

Fadai, D. (2007). Utilization of renewable energy sources for power generation in Iran. *Renewable and Sustainable Energy Reviews,* 11(1): 173-181.

GreenLabelsPurchase (2011). GreenLabelsPurchase.

IIES (2010). Hydrocarbon Balance 2008. *Institute for International Energy Studies (IIES)*. Tehran, Iran.

Iran, S. C. o. (2010a). Statistical Pocketbook of Islamic Republic of Iran. *Statistical Center of Iran*. Tehran, Iran.

Iran, C. B. o. (2010). Central bank reports bulletin. *Iran central bank reports bulletin*. Tehran, Iran.

Mahlia, T., H. Masjuki, et al. (2002). Theory of energy efficiency standards and labels. *Energy Conversion and Management*, 43(6): 743-761.

Mahlia, T., H. Masjuki, et al. (2002a). Development of energy labels for room air conditioner in Malaysia: methodology and results. *Energy Conversion and Managemen,t* 43(15): 1985-1997.

Mahlia, T., H. Masjuki, et al. (2002b). Potential electricity savings by implementing energy labels for room air conditioner in Malaysia. *Energy Conversion and Management*, 43(16): 2225-2233.

Mahlia, T., H. Masjuki, et al. (2002c). Economical and environmental impact of room air conditioners energy labels in Malaysia. *Energy Conversion and Management*, 43(18): 2509-2520.

Mahlia, T., H. Masjuki, et al. (2005). Energy labeling for electric fans in Malaysia. *Energy Policy*, 33(1): 63-68.

Mazandarani, A., T. Mahlia, et al. (2010). A review on the pattern of electricity generation and emission in Iran from 1967 to 2008. *Renewable and Sustainable Energy Reviews*, 14(7): 1814-1829

Meier, A. K. and J. E. Hill (1997). Energy test procedures for appliances. *Energy and buildings,* 26(1): 23-33.

Mohammadnejad, M., M. Ghazvini, et al. (2011). A review on energy scenario and sustainable energy in Iran. *Renewable and Sustainable Energy Reviews*.

Mohammadnejad, M., M. Ghazvini, et al. (2011). Estimating the exergy efficiency of engine using nanolubricants. *Energy education Science and Technology Part A*, 27(2): 447-454.

Parsafar, N., S. Mirzaee, et al. (2010). Transportation Energy Data Book 2008, *Optimize Fuel Consumption Organization*. Tehran, Iran.

Power, M. o. (2010). Energy Balance 2008. *Ministry of Power*. Tehran, Iran.

Pucher, J., H. Park, et al. (2005). Public transport reforms in Seoul: Innovations motivated by funding crisis. *Journal of Public Transportation*, 8(5): 41.

Raimund and Fickl (1998). Fuel Economy Labelling of Passenger Cars and its Impacts on Buying Behaviour and CO_2 Emissions. *The Speeches*: 27.

Saidur, R., A. Atabani, et al. (2011). A review on electrical and thermal energy for industries. *Renewable and Sustainable Energy Reviews*, 15(4): 2073-2086.

Saidur, R., H. Masjuki, et al. (2005). Labeling design effort for household refrigerator-freezers in Malaysia. *Energy Policy*, 33(5): 611-618.

Sustainability, D. o. (2011). Department of Sustainability - Fuel consumption label.

SUNA (2010). Renewable energy research and technology bureau. *New energy source organization (SUNA)*.Tehran, Iran,

Turiel, I., B. Atkinson, et al. (2001). Energy and carbon impact of new US fluorescent lam ballast energy efficiency standards. *Energy Efficiency in Household Applicances and Lighting*. Berlin.

Turiel, I., T. Chan, et al. (1997). Theory and methodology of appliance standards. *Energy and buildings*, 26(1): 35-44.

UN (1991). Energy statistics: a manual for developing countries. *United Nations*. New York.

Wikipedia (2010). *New European Driving Cycle*. Retrieved 2011 from http://en.wikipedia.org/wiki/New_European_Driving_Cycle