Fuel Efficient Road Transport System : A Review

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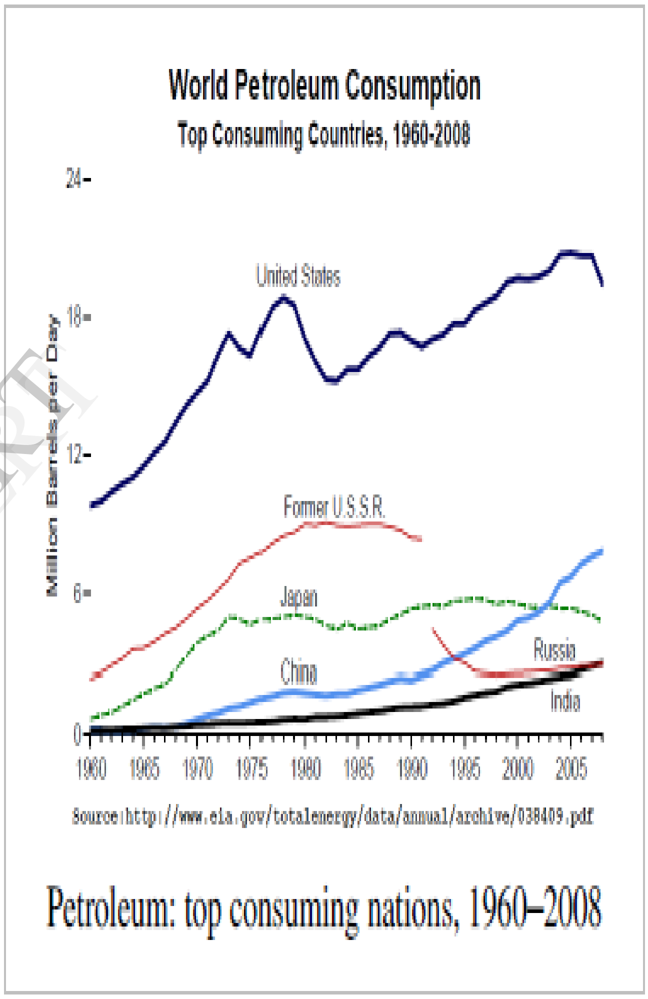
Abstract - **For developing a better economy there is a need of developing an energy-efficient and environment friendly road transport system. India is one of the fastest growing and largest emerging market economies. The Indian economy is one of the fastest growing economies and is the 12th largest in terms of the market exchange rate at $1,430.02 billion (2010 India GDP). In terms of purchasing power parity, the Indian economy ranks the fourth largest in the world. By 2020, India is expected to be in the top 10 largest economies of the world. Rapid economic growth is usually connected to a rapid expansion and highly profitable road transportation. Transportation is a major consumer of petroleum fuels whose prices are set to rise due to the decreasing reserves. There is a need of a more efficient transportation system.**

Key Words: Transportation, petroleum fuels, consumer, transport system, economies

INTRODUCTION

India is one of the fastest growing and largest emerging market economies (Wilson and Purushothaman, 2003; Economy Watch, 2010). According to W.H.O. the population of India is almost 1,245,910,000 (June 27, 2014) i.e. 17.4% billion people of the total population of the world. To support the population, huge amount of petroleum energy is being consumed in highway transportation sector which in turn cost a huge amount of Indian rupees.

Since 1970's, many programs have been initiated almost in most of the countries of the globe to reduce fuel consumption in the transportation sector. Transportation is a major consumer of petroleum fuels whose prices are soaring high due to decreasing reserve. Relying on fossil fuels can compromise trade balances ,national security, air pollution and climatic disturbances. New generation of vehicles, alternative fuels and propulsion systems and intelligent transport system are the technological solution. Other non-technological solutions are innovative land use, transportation policies, adjustment in the relative prices of location and transport, transportation supply and demand management
Figure 1 and table 1 shows the petroleum consumption of the topmost countries of the glob



Source : Wikepedia

Fig. 1: Graph showing increase of oil consumption by the top oil consuming countries.

Table 1: Top 10 petroleum energy consuming countries of world.

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Rank	Country/Region	Oil - consumption (bbl/day)	Per Capita (bbl/day)	Date of information
-	*World*	93,250,000	.012	2010 est.
1	United States	18,840,000	.059	2011 est.
-	European Union	12,800,000	.025	2011 est.
2	China	9,790,000	.0071	2011 est.
3	Japan	4,464,000	.035	2011 est.
4	India	3,292,000	.0026	2011 est.
5	Russia	3,196,000	.021	2012 est.
6	Saudi Arabia	2,817,000	.093	2011 est.
7	Brazil	2,594,000	.012	2011 est.
8	Germany	2,400,000	.029	2011 est.
9	Korea, South	2,301,000	.045	2011 est.
10	Canada	2,259,000	.063	2011 est.

Source : Wikepedia

Based on the environmental issues and for the well being of life on earth, it is important to develop the transportation system to offer enough mobility and on the other hand use far less energy. This is possible by developing a profound relationship between passenger and freight transport and energy consumption.

Technological strategies like new generations of vehicles, alternative fuels, propulsion systems and intelligent transport technologies for traffic management are some of the key solution. Other non-technological measures like innovative land use, transportation policies, adjustment in the relative prices of location, transportation supply and demand management.

In this paper, factors and possible solutions of developing a good and energy-efficient transportation system are described

1. FACTORS AFFECTING FUEL CONSUMPTION

Fuel consumption in transportation system depends on :
1. Amount of travel undertaken
2. Efficiency of vehicle

The most effective strategy is to reduce the amount of travel. Another strategy is to shift from private vehicle to mass transport. The fuel efficiency i.e. fuel consumption per vehicle-km of road transportation depends on:

- Vehicle
- Traffic
- Driver
- Roadway

1.1 The Vehicle:

Fuel efficiency in India has been improving in the past 20 years starting from 1990 onwards. There has been substantial induction of new technology in the personalized motor vehicles. However, in respect of trucks and buses, such technology up-gradations have been somewhat slow. Low diesel prices in the past and extreme overloading made possible by lax implementation of rules and regulations (which by themselves not being very stringent), unhelpful of tax regime and congested roads – all led to delays in the induction of new technology in the transport industry. Moreover, the fabrication of bus body and the truck body has hitherto been virtually unregulated. The bus body code has been evolved and work on the same in respect of trucks is in progress. In order to implement these norms, a system of accreditation of body builders needs to be evolved. It has been assessed that multi-axle vehicles save fuel upto the tune of 50% per tonne km. Reduced fuel consumption apart from monetary saving also has a salutary effect on reduction of pollution. Multi-axle vehicles are also more road-friendly as these put less stress on the road infrastructure. In fact, one multi-axle vehicle can be deemed equivalent of the load carrying capacity of four numbers of rigid axle-vehicles. In the advanced countries, bulk transportation is done on multi-axle vehicles

While the rigid vehicles do the distribution at the local levels. However, in India generally rigid vehicles are used for both highway operations as also at local levels. It is assessed that whereas a rigid vehicle covers about 250 kms per day, the multi-axle vehicle covers around 400 kms per day. Similarly, emissions from the multi-axle vehicles tonne of load carried are also correspondingly lower. It is, therefore, necessary to apply differential taxation to encourage the use of multi-axle vehicles. There is an urgent need that the country should profit from the increased use of low tare weight and heavy haul multi axle trucks, which are more fuel-efficient.

1.2 The Traffic :

In developing countries like India, the rapid growth of cities resulted in manifolds increase in motorized vehicles, especially during the peak hours. The traffic flow conditions have significant impact on fuel consumption. Factors such as speed profiles, number of stops and also accelerationdeceleration manoeuvres affect the amount of fuel consumption per kilometre of travel. Congestion problems in cities simultaneously alarm both the users as well as the decision makers. Controlling, suggesting remedial measures, making changes to the existing traffic system in urban India is becoming more and more complex day after day. Traffic here includes innumerable classes of vehicles having different operating characteristics.

1.3 The Driver :

Fuel consumption also relates with the driving style of the driver. Drivers in India do not follow lane discipline in spite of lane markings on the road. Rash driving like rapid acceleration and de-acceleration increases the fuel consumption. Driving in a steady manner which we often term "environmental driving" minimises fuel consumption as such driving behaviour decreases the emissions.

1.4 The Roadway :

Geometric design as well as pavement surface design largely affects the amount of fuel consumption. Improper design like steep gradients, sharp curves, poor surface conditions result in higher petroleum energy consumption

2. HIGHWAY MAINTENANCE:

Heavy traffic loads and increasing frequency of load repetition along with the climatic changes affects a lot in the life span of the roadways. India is a country with heavy monsoon rainfall which lasts for months, drains away the lifespan of the highways and all other roadways which were design to last for years get shortened in few months due to the frequent change is temperature and moisture content in soil. Poorly maintained roads have been known to increase fuel accelerated wear and tear of vehicles. Early preventive maintenance and timely rehabilitation is necessary to keep the roads is good conditions and minimise fuel consumption. Douglas and Valsangkar(1992) find out a relationship between stiffness and fuel consumption on unsealed access roads that road stiffness reduces fuel consumption and operating costs. Using geogrid or geotextile can significantly increases the stiffness of a low-standard access roads. India has an extensive network of such roads especially in rural areas and there is a tremendous potential for achieving fuel economies.

3. MODES OF TRAVELS :

In urban areas, modes of travel is dominated by private cars, two-wheeler vehicles, buses, suburban train, cycling and walking. Travel undertaken on private motor cars with solo drivers should be discouraged as it is fuel consuming. Travel undertaken using public transportation should be encouraged. The public transportation system should be made reliable, punctual, comfortable, clean, safe, shorter travel time and with economical fare. Urban public transportation in India is **facing** a big problem of ever-increasing time to make a journey followed by long waiting time. For a more fuel efficient system, it is needed to reduce the road congestion which can be achieved easily and economically by decreasing use of low capacity vehicles like cars , 3-wheelers etc and increasing use of high capacity vehicles i.e. buses. A bus saves space, fuel and also reduces pollution

4. TECHNOLOGY:

In the technology world, the latest advancement is only as good as the next thing coming down the line. The auto industry is constantly bringing us new technologies, whether it be for safety, entertainment, usefulness or simply for pure innovation.

Many new car technologies are either specifically built for safety or at least have some sort of safety focus to them. Some of the latest car innovations are some truly exciting technologies that could revolutionize not just the automotive industry but human transportation in general. In the area of the vehicle technology it can be categorised under three dimensions. They are:

1. Engine: Constructing a more fuel efficient and less emission engine, including improvements in reducing engine weight and rolling resistance. encouraging the development of alternative engines, alternative transmissions, regenerative braking etc.

2. Aerodynamics: the body of the vehicle should be streamlined into a more aerodynamic shape.

3. Alternative fuels: Use of alternative fuels like CNG , ethanol, methanol-ethanol, hydrogen, fuel cells and electric vehicles etc.

4.1 Engine: There are lots of advancement in the automobile technology starting from fuel economy to green vehicles. Super ultra-low emission vehicle (SULEV) is a U.S. classification for passenger vehicle emissions. The classification is based on producing 90% less emissions than an equivalent gasoline-powered vehicle. SULEV is a stricter standard than LEV (Low Emission Vehicle) and ULEV (Ultra-Low Emission Vehicle), however not as strict as PZEV (Partial Zero Emission Vehicle). In California, manufacturers of SULEVs can be given a partial credit for producing a Zero Emission Vehicle (ZEV) and so a vehicle of this type can be administratively designated as a Partial Zero-Emission Vehicle (PZEV). In order to qualify as a PZEV, a vehicle must meet the SULEV standard and, in addition, have zero evaporative emissions from its fuel system plus a 15-year/150,000 mi (241,402 km) warranty on its emission-control components. In the case of hybrid vehicles this warranty is extended to the electric propulsion components (electric motor/generator/starter, battery, inverter, controls) and their mechanical interface to the driveline - potentially a distinct advantage to the owner of such vehicle. Table 2 shows the Indian emission standard for 4-wheel vehicles.

Table 2 : Indian Emission Standards (4 – wheel vehicles)

Standard	Reference	Date	Region
India 2000	Euro I	2000	Nationwide
Bharat Stage II	Euro 2	2001	NCR*,Mumbai, Kolkata, Chennai
		2003.04	NCR*,13 Cities†
		2005.04	Nationwide
Bharat Stage III	Euro 3	2005.04	NCR*,13 Cities†
		2010.04	Nationwide
Bharat Stage IV	Euro 4	2010.04	NCR*,13 Cities†
*National Capital Region(Delhi),†Mumbai,Kolkata, Chennai, Bengaluru, Hyderabad, Ahmedabad, Pune,Surat, Kanpur, Lucknow,Sholapur, Jamshedpur and Agra.			

Source : Indian Emission Standard- Wikepedia

The Indian emission standards for new heavy – duty diesel engines – applicable to vehicles of GVW> 3,500 kg – are listed in Table 3.

Table 3: Indian emission standards for new heavy - duty diesel engines

Year	Reference	Test	CO	HC	NO_X	PM
1992	-	ECER49	17.3-32.6	2.7-3.7	-	-
1996	-	ECER49	11.20	2.40	14.4	-
2000	Euro I	ECER49	4.5	1.1	8.0	0.36*
2005†	Euro II	ECER49	4.0	1.1	7.0	0.15
2010†	Euro III	ESC	2.1	0.66	5.0	0.10
		ETC	5.45	0.78	5.0	0.16
2010‡	Euro IV	ESC	1.5	0.46	3.5	0.02
		ETC	4.0	0.55	3.5	0.03
*0.612 for engines below 85 kW † earlier introduction in selected regions, see Table 2						

Source : Indian Emission Standard- Wikepedia

The fuel economy of an automobile is the fuel efficiency relationship between the distance travelled and the amount of fuel consumed by the vehicle. Consumption can be expressed in terms of volume of fuel to travel a distance, or the distance travelled per unit volume of fuel consumed.Since fuel consumption of vehicles is a significant factor in air pollution, and since importation of motor fuel can be a large part of a nation's foreign trade, many countries impose requirements for fuel economy. Miles per gallon (mpg) is commonly used in the United States, the United Kingdom, and Canada (alongside L/100 km). Kilometres per litre (km/L) is more commonly used elsewhere in the Americas, Northern Europe, Asia, parts of Africa and Oceania. When the mpg unit is used, it is necessary to identify the type of gallon used, as the imperial gallon is 4.5 liters and the US gallon is 3.785 liters. Fuel consumption standards for some countries are given in table 4.

Table 4: Fuel consumption standards for some countries.

Country	**2004 Average**	**Requirement**			
		2004	**2005**	**2008**	**Later**
People's Republic of China			6.9 L/100 km	6.9 L/100 km	6.1 L/100 km
United States	24.6 mpg (9.5 L/100 km) (cars and trucks)	27 mpg (8.7 L/100 km) (cars only)	`		35.5 mpg 6.6 L/100 km (2016)
European Union					5 L/100 km (2012)
Japan					6.7 L/100 km CAFE eq (2010)
Australia	8.08 L/100 km CAFE eq (2002)	None			6.7 L/100 km CAFE eq (2010) (voluntary)

4.2 Aerodynamic: An automobile will integrate the wheel arcs and lights into the overall shape to reduce drag. It will be streamlined; for example, it does not have sharp edges crossing the wind stream above the windshield and will feature a sort of tail called a fastback or kammback or liftback

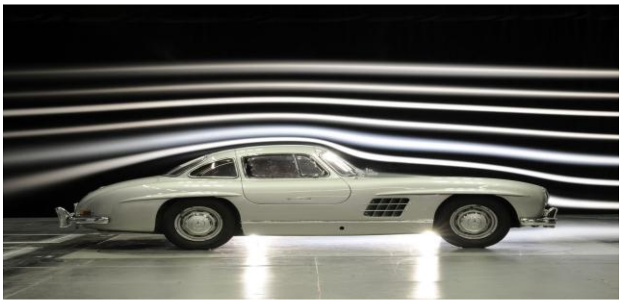

Figure 2: Volkswagon Source : Wikepedia

Note that the Volkswagen 1-litre car try to reduce the area of their back. It will have a flat and smooth floor to support the Venturi effect and produce desirable downwards aerodynamic forces. The air that rams into the engine bay, is used for cooling, combustion, and for passengers, then reaccelerated by a nozzle and then ejected under the floor. For mid and rear engines air is decelerated and pressurized in a diffuser, loses some pressure as it passes the engine bay, and fills the slipstream. These cars need a seal between the low pressure region around the wheels and the high pressure around the gearbox. They all have a closed engine bay floor. The suspension is either streamlined or retracted. Door handles, the antenna, and roof rails can have a streamlined shape. The side mirror can only have a round fairing as a nose. Air flow through the wheel-bays is said to increase drag (German source) though race cars need it for brake cooling and many cars emit the air from the radiator into the wheel bay. More aerodynamically streamlined body helps reduce the fuel consumption by reducing the frictional force exerted from the atmosphere to the speeding vehicle as the engine consumes more fuel to overcome the friction. Figure 3 shows horsepower V_S speed chart with relation to aerodynamic drag to the vehicles.

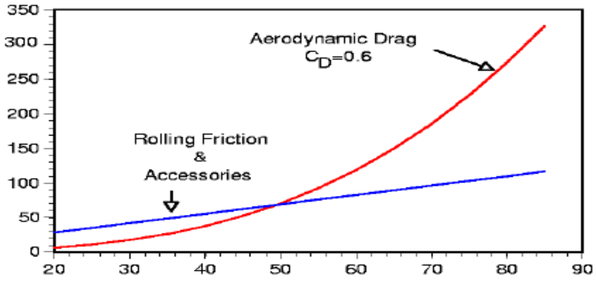

Figure 3: Horse power Vs speed chart with relation to aerodynamic drag

4.3 Alternative fuel: In this era of new technologies different types of fuel for substituting petrol for use in automobiles are developed. To safeguard environment governments must encourage the use of alternative fuels by not imposing the fuel tax applied to petrol. Some alternative fuels for petrol are:

1. Natural gas and propane
2. Methanol and ethanol
3. Oxygenated fuels
4. Gasoline reformulation
5. Rape seed oil
6. Fuel cells

5. ALTERNATIVE FUEL VS PETROL FOR THE ENVIRONMENT :

Alternative fuels are environmentally cleaner and produce substantially lower emissions as compared to automotive fuel. Table 5 shows the comparison between the emissions produced by the alternative fuels and petrol.

Table: 5 Comparison of emission produced by the alternative fuels and petrol.

Fuel	**Reactive HC**	**CO**	**NOx**	**Toxic emissions**
Natural gas	Much lower	Lower	Similar	Much lower
Propane	Lower	Lower	Similar	Lower
Methanol	Lower	Similar	Similar	Similar
Ethanol	Lower	Similar	Similar	Similar
Ethanol blend	Slightly lower	Lower	Slightly lower	Similar

6. PROPULSION TECHNOLOGIES

Different type of alternative propulsion technologies regarding fuel efficiency and fuel flexibility of highway vehicles and reducing vehicle emission are being developed and tested by the U.S. Department of Energy. Development of light duty vehicles like gas turbine, two-stroke cycle spark ignition, electric engines and hybrid approaches based on batteries and fuel cells brings the level of propulsion technology into a different level. Development of an environmentally clean Guideway Bus System in Japan which uses a hybrid power plant (consisting of a diesel engine and electric motor) which is suitable for small city transportation can also be applied in small cities of India.

7. I.T.S FOR FUEL EFFICIENCY

Over the last 20 years, American auto industry claimed that air pollutants in car exhaust has been reduced by 96%.In U.S., after the advent of car and the construction of the interstate system. Intelligent Transportation Systems helps in improving fuel efficiency and highway safety, reducing congestion and travel times. It also improves vision enhancement, navigation, route guidance systems and satellite-based emergency roadside assistance. It provides information on type of assistance needed (roadside or emergency), vehicle identification, vehicle position (latitude and longitude), last recorded direction and speed of the vehicle and the vehicle's call-back telephone number with pushing of a single button

8. STRATEGIES FUEL EFFICIENCY AND TRAFFIC CONTROL

To improve fuel efficiency in transportation system the best strategy is to reduce the amount of travel, shift to fuel-efficient modes, driving in a fuel-efficient style, improving traffic flow and the provision of good roads. Though a long-term measure, changes in physical planning will give a profound effect on the level of transport demand. Better planning of sites for production, warehousing etc. will result in shorter trips and better opportunities to use rail and other mass transport modes. Price and Probert (1995) suggested for alternative fuels and shifting from road to rail transport. They contend that car ownership should only be perceived as luxury.

ITS technologies will be able to improve traffic flow, reduce fuel consumption and emissions. It will also provide:

1. trip planning and dynamic route guidance to the traveller.
2. traffic circulation measures
3. vehicle navigation.

CONCLUSIONS

Fuel efficient transportation system is a sustainable transportation system. In particular, the system will have the following features:

1. Less trips i.e. reduce travel demands
2. Reduce trip length
3. Increase load factor i.e. less vehicle-kilometers per tonne-kilometers
4. Improve fuel efficiency i.e. less energy use per vehicle kilometers
5. Less emissions from vehicle

For achieving a fuel efficient system we should encourage the use of advanced technologies like:

1. ITS,
2. New generation vehicles,
3. Advanced propulsion technologies,
4. Alternative fuels
5. Effective demand management i.e. Land-use, pricing and regulations.

The most efficient machines for converting energy to rotary motion are electric motors, as used in electric vehicles. However, electricity is not a primary energy source so the efficiency of the electricity production has also to be taken into account. Policies to change urban densities and zoning should also be encouraged.

Levels	Areas to be addressed
Primary	Technology ,design, fuel, combustion, exhaust, electricity, ac/dc, motor-design, transmission, gear, wheel/tires, aerodynamics, alternate fuels
Secondary	Infrastructure, road construction, road geometry, urban spatial structure, land-use ,mode-coordination, structure of fare, traffic-management
Tertiary	Operational,scheduling, routing, management of crew and fleet, reliability, behaviour of driver

In the future, hydrogen cars may be commercially available. Potentially the atmospheric pollution could be minimal, provided the hydrogen is made by electrolysis using electricity from non-polluting sources such as solar, wind or hydroelectricity or thermo-chemically by the use of the Thorium fuel cycle in a molten salt reactor. In any process, it is vitally important to account for all of the energy used throughout the process. Thus, in addition to the energy cost of the electricity or hydrogen production, we must also account for transmission and/or storage losses to support large-scale use of such vehicles. For this reason the use of the idea "zero pollution" should be avoided.

From time to time, governments have to introduce policies and enact legislations with a view to reducing fuel consumption and carbon-dioxide emissions from motor vehicles. In several instances, these policies force many people to do things that they don't want to do. For example, raising fuel taxes is unpopular with most drivers while setting stringent average fuel efficiency standards for new vehicles is unpopular with auto-manufacturers. Nearly all the improvements come from the supply-side response with very little attributable to consumers shifting among vehicle classes because the consumers favour the more efficient vehicles produced. However, as the more fuel efficient vehicles penetrate the entire stock, scrappage rage declines and new car sales could drop.

Old vehicle scrap program should be encouraged. Older, highly polluting vehicle can voluntarily be sold to a designated agency. California has a voluntary scrap program in which $700 is paid for scrap vehicles. In U.S. it is recommended to scrap vehicles which are over 10 years old and to remove vehicles from the roads which cause higher emissions

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