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Research paper

The Eco-Driving Behaviour: A Strategic Way to Control Tailpipe Emission

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Abstract

The global auto industry is responsible for 15.9% of carbon emission (OICA) and among that, vehicle users are responsible for around 80% of carbon emission (JAMA). Awareness about environmental problems caused by this emission is rapidly increasing among people and governments are organizing various campaigns to make people familiar with the eco-driving concept. Vehicle users do not realize that their driving style has a direct influence on fuel consumption and this, in turn, leads to unwanted carbon emission. Therefore, there is a need to understand the car users' eco-driving behavior and explores the awareness level of passenger car users. Data has been collected from 400 respondents through the help of a structured questionnaire with a focus on eco-driving behavior practices. Analysis of this data showed that the pressure given to accelerate the engine is transformed into tailpipe emission. Therefore, this study highlights the importance of inculcating eco-driving behavior among car users in particular and vehicle users in general.

Keywords: *Eco-driving behavior, environment, automobile, tailpipe emission, passenger car.*

1. Introduction

The automobile industry is one of the fastest growing industries in the world. Autos are considered a key sector for the economies and have contributed hugely to the economic development of a nation and also to the growth of allied sectors. Every year automakers make millions of vehicles with different variety and these vehicles are instantly on the roads. During 2000-16 over 1.245 billion Passenger Cars and Commercial Vehicles (PCs & CVs) were produced globally, among that India has contributed up to 44.086 million vehicles (OICA, 2017). China is the largest producer in the world followed by Japan, Germany, USA, South-Korea, India, and others (OICA, 2017).

In 2016 around 3.677 million of passenger cars were produced in India and the number is expected to grow steadily in the coming years reaching four million by the end of 2017 (ACMA, 2017). At present, India is the 6th largest car manufacturer and it also holds the 2 place in the manufacture of both two-wheelers and buses (SIAM, 2017).

India has world's 2nd largest population, with 1.343 billion people belonging to the younger generation (Worldmeters, 2017). The Indian automobile sector fully liberalized by 2000, has ensured that many foreign automakers strongly establish their business and some of them also collaborate with Indian automakers. The automobile industry has been contributing to the Indian economy with an average growth rate of 7.1% of GDP for the last five years. There is tremendous growth rate in the production of autos in the past decade. Now India is considered the 3rd largest investor base in the world market (SIAM, 2017). From 2012-17, the total investment on infrastructure was over $ 1 trillion (ACMA, 2017). Among that $ 172 billion being invested in road infrastructure facilities (D'Souza et. al, 2007). Subsequently, foreign automakers have raised their investment up to $ 15.79 billion in Indian market from April 2000 to September 2016 as declared by India Brand Equity Foundation (IBEF, 2017).

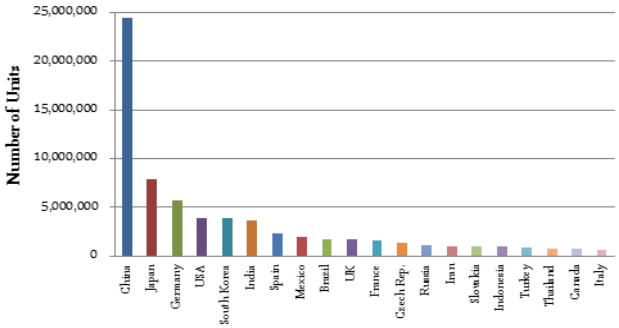

Fig. 1: Production of World Passenger Car – 2016
Source: OICA International Organization of Motor Vehicles Manufacturers (2017).

Already the market for automobiles has expanded tremendously, especially for the passenger car segment. Some of the major manufacturers are Ford, Hindustan, Hyundai, Mahindra, Maruti, Tata,

Volkswagen and others (Safai, et. al., 2012). At present, there are more than 22 automakers that have their own manufacturing plant in India. Hence the production of vehicles has increased at a rapid pace. Around 88% of the vehicle is sold in the domestic market and the remaining 10% is exported to China, Brazil, UAE, Thailand, South Africa, America and Europe (SIAM, 2016). Maruti is the leading market share holder, followed by others. Some of the famous brands manufactured in India are Maruti-Alto & A-Star, Hyundai - i10, i20 & EON, Tata-Indica, Mahindra-Bolero, Volkswagon-Polo, Nissan-Micra etc. (SIAM, 2017).

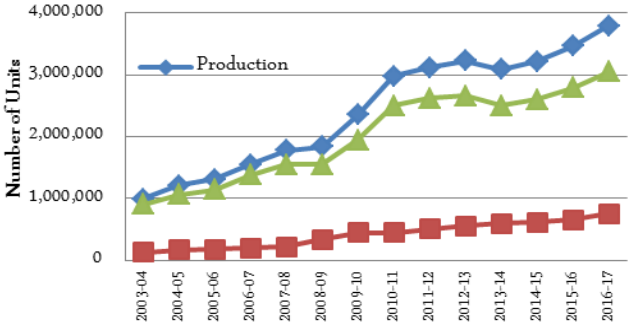

Fig. 2: Status of Passenger Cars in India
Source: Society of Indian Automobile Manufacturers SIAM (2017).

Furthermore, Automotive Component Manufacturers Association of India (ACMA) has found that a large number of young Indians are more curious to use the car. Out of thousand people, 25 Indians have their own cars. However, International Organization of Motor Vehicle Manufacturers (OICA) shows low car ownership rate in India when compared to the world Austria has 727 cars per thousand people, followed by Denmark, France, Germany, Greece, and others (OICA, 2017). But comparing the pollution level the Indians, the Chinese and the Brazilians are releasing more tailpipe emission (Ramachandra, et. al, 2015). By 2007, it is estimated that around 806 million cars and light commercial vehicles were on the road and they consumed around 980 billion liters of petrol and diesel, one-third of which was consumed by the Brazil, Russia, India, China (BRIC) country. Indians polluted more since 452.11 tonnes of carbon emission was released (Plunkett, 2008).

2. Literature Review

2.1 Environmental Consequences

There was a massive production of vehicles over the past decade and it has a tremendous impact on our ecological system (D.Arokiaraj, 2017). During the 1970's itself, the issue was raised at local, national and international levels regarding the effect of pollution on the environment. The problem of pollution was becoming a major cause of concern for all the countries (Golob 1998). The major environmental problems are global warming, climate change, greenhouse gases (GHG's), ozone layer depletion, acid rain, reducing the quality of air, noise, and pollution of land and water (S. Krinke, 2011). Roshan Ali reported that "the situation is even more worst with hydrocarbons raising global warming and particulate matter were increased from 1.94 tonnes to 11.9 tonnes a day over the last two decades," (Borzoueisileh, et. al., 2014; Pratheepkumar, 2017). Environmental issues are becoming one of the major unsolved problems among all countries and especially among the developing countries like India, China, and Brazil. Globally, transportation sector itself contributes 16% of carbon emission and it leads to 15% of GHG's (Golob & Hensher). India is ranked the 4th in GHG emission just behind US, China, and Europe (FIIA- Foreign Investment Implementation Authority, 2010; OICA).

Chennai is the 6th most populous and the 4th largest metropolitan city in India with 4.68 million residents and it is the capital city of Tamil Nadu. The Tamil Nadu Pollution Control Board (TNPCB) has confirmed that air pollution is steadily increasing at an alarming rate in both residential and commercial regions (Syed Ali Mujtaba, 2017). The World Health Organization (WHO) has fixed 85 decibels as a permissible limit for noise pollution (Srivel, 2018). The National Pollution Control Boards (NPCB) has estimated that the noise level in Chennai has crossed 129 decibels. The pollution level of noise, air, and water is horrific in Chennai and the residents are forced to live in this condition which is far below the standards set by the WHO. Every day 700 new vehicles are being added on Chennai's roads that further raise the environmental burdens (Stalin, 2015).

Unfortunately, the environmental burden is much increased by using passenger cars, heavy and light commercial vehicles, bikes, buses and other autos that even more raise the pollution level (Golob 1998). The vehicle users are mainly responsible for this vulnerability caused in the form of tailpipe emission that carries Co, Co2, So2, No2, N2O, HC, VOCs, PM10 and PM2.5 (Arokiaraj, 2015). The particulate matter is particles found in the air including smoke, dirt, soot, dust, and liquid droplets. Further, each substance has its own adverse effects on the environment. It causes several serious damages on the vegetation as well as on the human's health (Prothero & Fitchett, 2000). It has a direct and indirect impact on humans by damaging their internal and external organs through various diseases such as a headache, chest pain; reduced lung abilities; neurological disorders; impaired kidneys; brain, liver and cardiovascular system damages; breathing, eye and reproductive system problems; skin and heart diseases; nausea and fatigue; and disintegration of haemoglobin in our blood (Abe, 2011; Arokiaraj, 2015; Jamson et. al, 2015). Air pollution is havoc for the city residents and they have been paying a high price for their lives. It is one of the deadliest forms of pollution and is becoming the 4th risk factor for premature deaths worldwide (Ramachandra, et. al., 2015). The WHO reported that over 92% of world population is inhabited in the polluted cities. As per the report of Greenpeace India 2017, air pollution causes 1.2 million deaths annually in India and every minute two Indians are dying (WHO, 2014). So there is an urgency to bring down the emission by simply following the eco-driving techniques.

2.2 Eco-Driving Behavior of Vehicle Users

The extensive literature reviewed has been done on the eco-driving behavior of vehicle users and on their environmental concerns. These are numerous studies conducted in the developed countries for effecting control over the level of pollution (Abe, 2011; Leduc et. al, 2010; Williamson et. al, 2006). As a result of these extensive studies, the eco-driving behavior practices and techniques have come into existence. Eco-driving is "a systematic way of driving a car that can reduce fuel consumption, emission, greenhouse gas emission, accident rate and energy efficient" (Wada et. al, 2011; D'Souza et. et al, 2007; JAMA, 2016). It not only saves the environment but also reduces the fuel consumption. Eco-driving is related to driving safely and smartly, by accelerating or deaccelerating the engine smoothly. It involves a set of steps, techniques, and activities (Barkenbus, 2010; Wada et. al, 2011).

The simple driving practices which will lead to eco-driving behavior are: always schedule the shortest route plan (Jamson, 2015; Ando & Nishihori, 2011, JAMA, 2016; David, 2014), accelerate the engine gently, drive at a constant speed between 40 - 60 km (McIlroy & Stanton, 2015; Williamson et. al, 2006,), obey the traffic rules (Borzoueisileh et. al, 2014, JAMA), maintain and service the engine properly for smooth functioning (Abe, 2011), check the tire pressure regularly (Leduc et. al, 2010, JAMA, 2016), reduce unnecessary luggage or weight (Wada et. al, 2011), switch off engine during traffic jam (Barkenbus, 2010, JAMA, 2016), check the vehicle emission level frequency (JAMA, 2016), always tighten the fuel tank cap after filling poured (D'Souza et. al, 2007; David, 2014), give left to others, use public transport occasionally (Andrieu & pierre, 2012, JAMA), avoid unnecessary braking and

drive with open windows Japan Automobile Manufacturers Association (JAMA, 2016).

A lot of improvement has been witnessed in engine technology and car performance over the past 15 years. Even then most of the drivers' driving style and attitude have not changed on par with these techniques. Many theories and conceptual models, developed to explain behavioral changes, concluded that behavior changes in various stages or steps, moving a person from unknowingly performing an "unwanted" behavior to automatically and ideally unconsciously, performing the "wanted" behavior (Ando & Nishihori, 2011; D'Souza et. al, 2007). Drivers most of the times, do not realize that their driving style has induced fuel expenses, led to surplus emissions and increased fuel costs (Jamson et. al, 2015; Arokiaraj, 2015).

The eco-driving behavior is a driving style that can be applicable to any kind of vehicle and it enhances conditions more economically as well as ecologically (Ando & Nishihori, 2011). Minor changes in the driving style would create a major impact on the carbon emission and improve the fuel efficiency (Arokiaraj & Banumathi, 2015). More than two million tonnes of carbon dioxide emission can be reduced by creating the eco-driving awareness among vehicle users (Safai et. al, 2012). Although promotion of eco-driving concepts has begun in major developed countries, such promotion is not seen in India. In Austria, eco-driving means "climate: active mobile", a fuel save initiative whereas in Germany "new driving – clever, safe, further" and in Netherlands "the new driving" (Borzoueisileh et. al, 2014; D'Souza et. al, 2007; Krinke, 2011; Safai et. al, 2012; Ramachandra et. al., 2015).

Countries like Australia, Canada, Germany, Netherlands, the United Kingdom, and the United States are voluntarily promoting the eco-driving behavior programs. It is found that these practices have reduced 30% of fuel consumption, as well as 95% of accident rates. (Andrieu & Pierre, 2012). The study conducted in Japan by Ryosuke Ando and Yasuhide Nishihori found that the practice of eco-driving has reduced 10 - 20% of fuel consumption along with stress level, accident rata, and traffic jam. The analysis of Sivak and Schoettle has pointed out that road and vehicle type can improve up to 20-40% of fuel economy (Sivak, 2009). So, it is very important to understand the eco-driving behavior for environmental protection as well as for fuel efficiency.

3. Methodology

A questionnaire was prepared based on the review of literature relating to the eco-driving behavior of vehicle users. Quantitative research was conducted with the help of exploratory research design. Primary data was collected from select major areas in Chennai region of Tamil Nadu. Around 400 samples were gathered through systematic sampling method. The questionnaire was distributed to passenger car users focusing on the eco-friendly driving practice. A five-point Likert scale strongly agree | agree | neutral | disagree | strongly disagree was used. Correlation, regression and mean score were performed using Statistical Package for the Social Sciences (SPSS).

The demographic profile of respondent was analyzed with the help of percentage method. Out of the 400 passenger car users surveyed, 76% of them were male. Around 65% of the respondents were young, i.e., 20-30 years old. It is found that 37% of them have been driving their vehicles for the past one year. On an average, 5 years of driving experience was found among 32% of respondents. Most of them drive inside cities (44%) and some in highways (35%) with a speed of 100 km/h. 60% of them drive at 40-80 km/h inside the city. 70% of them drive carefully and also in a relaxed manner. All of them drive in cities, highways and rural areas and driving style and speed depends upon the area. Most of the respondents (75%) have small and medium size cars. Diesel vehicles were preferred by 57% followed by petrol vehicle (39%). On an average, they use 25 liters of fuel per month. More than 20 varieties of car models and all brand holders were represented in the sample.

The normality of data was verified with the help of Skewness and Kurtosis value. The values fell within the range of ± 1.96 which ensured the normality of the data. Reliability value was also verified with help of SPSS. Reliability means internal consistency of the data. Based on the value obtained, the overall reliability is .863. This is more than Cronbach's alpha a = 0.7 which proved eco-driving behavior is reliable. Further, the mean score was calculated for the behavior practiced by the passenger car users. It is found that the drivers gave more importance to accelerating the engine gently (mean value = 4.45), always planned the trip (mean value = 4.33), reduced unnecessary load on their car (mean value = 4.21), frequently checked their tire pressure (mean value = 4.15), maintained a steady speed (mean value = 3.99) etc.

The correlation test was performed to understand the relationship between the variables (Handy et. al., 2005). The dependent variable is eco-driving behavior and the independent variables are luggage, speed limit, turn-off, trip plan, usage of the air-conditioner, tire pressure, engine gently, noise pollution and steady speed (JAMA, 2016).

Table 1: The Mean Score of Eco-Driving Behaviour of Passenger Car Users

Eco-driving Behaviour	Rank	Mean	Std. Deviation
Engine Gently	1	4.45	0.63
Trip Plan	2	4.33	0.85
Luggage	3	4.21	0.84
Tire Pressure	4	4.15	0.99
Steady Speed	5	3.99	1.10
Speed Limit	6	3.95	1.21
Noise Pollution	7	3.94	1.00
Usage of Air-conditioner (AC)	8	3.79	1.09
Turn-Off	9	3.64	1.24

Insert Table 2: Correlation Analysis for Eco-Driving Behaviour Practice

Insert Table 3: Coefficient of the Regression Analysis

Thus the result predicted that accelerating the engine gently, regularly checking the tire pressure, maintaining a steady speed drive at 40-60 km/s, reducing maximum weight in the car, turning off the engine in a traffic jam, safely driving within the speed limit will positively influence the driving behaviour of the passenger car users. Whereas, the impact of the limited use of air-conditioners, scheduling the trip and reducing noise pollution was found to be insignificant. Based on the above model, it is very clearly indicated that accelerating the engine gently has a high impact on the eco-driving behavior of the passenger car users.

4. Conclusion

Based on the result, we can see that there is a direct relationship between pressure given to accelerate the vehicle and tailpipe emission. There is an increase in the fuel cost in such conditions. Hence, it is predicted that the more pressure given to the engine acceleration, the more there will tailpipe emission and fuel cost. Therefore, it is strategically very important to drive the vehicle in a relaxed manner. Based on the response, it is found that most of the respondents were aware of eco-driving techniques and had sound knowledge about their environmental problems, but it is also noted that they had given less importance to eco-driving practices. This study concluded that practicing eco-driving behavior improves fuel efficiency, reduces the tailpipe emission and ensures a safe drive. The government needs to organize awareness campaigns about eco-driving behavior for all vehicle users, was framed similarly to those of developed countries. Simply follow-

ing these eco-driving behavior techniques will certainly reduce 16% of carbon emission and also save fuel. The government should also make a policy to limit the production of conventional vehicles (i.e. diesel and petrol). They should also encourage the production of eco-friendly autos like electric, hybrid and fuel-cell vehicles.

5. Scope of Further Study

This study focused on the eco-driving behavior of passenger car users only and did not include light and heavy commercial vehicles, buses, three-wheelers, and two-wheelers. Further study can include other vehicles and factors like age of the vehicle, fuel adulteration, weight of the vehicle, the location of hometown, drive at traffic area, road infrastructure and others that lead to emission factors.

Acknowledgment

Dr. Arokiaraj David

I have 6 years of experience including five years of research and one year in academic. I have completed my Doctorate in the field of Environmental Marketing at Pondicherry University, Puducherry under UGC-Fellowship. I have completed my Master's Degree in Finance from Alagappa University and Business Management. My areas of major interest include Marketing Management, Environmental Marketing, Environmental Management System, Principles of Management and Human Research Management. I have several research publications in National and International Journal, these arrears in reputed academic and policy-oriented journals. I have good knowledge of various Research software SPSS, AMOS, STATA, and Smart PLS. My research interests are green marketing, consumer behavior, and policy analysis. I have authored, co-authored or edited and published by reputed international publishers. I have supervised several postgraduate students' dissertations at the college level.

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Table 2: Correlation Analysis for Eco-Driving Behaviour Practice

Correlations		Eco-driving behavior	Trip plan	Lug-gage	Tire pressure	Engine gently	Steady speed	Speed limit	Noise pol-lution	Usage of AC	Turn-off
Eco-driving behavior	Pearson correlation	1									
	P-Value										
Trip plan	Pearson correlation	.436**	1								
	P-Value	.000									
Luggage	Pearson correlation	.606**	.402**	1							
	P-Value	.000	.000								
Tire pressure	Pearson correlation	.764**	.382**	.403**	1						
	P-Value	.000	.000	.000							
Engine gently	Pearson correlation	.836**	.327**	.393**	.546**	1					
	P-Value	.000	.000	.000	.000						
Steady speed	Pearson correlation	.826**	.340**	.378**	.519**	.707**	1				
	P-Value	.000	.000	.000	.000	.000					
Speed limit	Pearson correlation	.555**	.220**	.239**	.424**	.490**	.455**	1			
	P-Value	.000	.000	.000	.000	.000	.000				
Noise pollution	Pearson correlation	.557**	.243**	.301**	.435**	.485**	.462**	.554**	1		
	P-Value	.000	.000	.000	.000	.000	.000	.000			
Usage of AC	Pearson correlation	.425**	.196**	.259**	.235**	.363**	.382**	.415**	.534**	1	
	P-Value	.000	.000	.000	.000	.000	.000	.000	.000		
Turn-off	Pearson correlation	.623**	.294**	.277**	.361**	.454**	.547**	.321**	.346**	.398**	1
	P-Value	.000	.000	.000	.000	.000	.000	.000	.000	.000	

** Correlation is significant at the 0.01 level (2-tailed).

Table 3: Coefficient of the Regression Analysis

	Unstandardized Coefficients		Standardized Coefficients	T value	P value	Collinearity Statistics	
	Beta	Std. Error	Beta			Tolerance	VIF
(Constant)	-.144	.287		-.502	.616		
AC	-.007	.050	-.002	-.132	.895	.637	1.570
Trip plan	-.063	.058	-.013	-1.082	.280	.761	1.315
Speed limit	.189	.046	.055	4.084	.000	.601	1.664
Noise pollution	.058	.059	.014	.976	.330	.528	1.892
Turn off	.524	.043	.157	12.054	.000	.644	1.552
Steady speed	.996	.062	.265	16.192	.000	.510	1.440
Engine gently	1.251	.064	.305	18.893	.000	.523	1.364
Tire pressure	1.224	.058	.293	21.249	.000	.577	1.733
Luggage	1.042	.060	.213	17.254	.000	.724	1.382

$$\textbf{Eco} - \textbf{driving behaviour} = -.14 + (1.251 * Engine\ gently) + (1.224 * Tire\ pressure) + (1.042 * Luggage) + (.996 * Steady\ speed) + (.524 * Turnoff) + (.189 * Speed\ limit) + (0.58 * Noise\ pollution) - (.007 * AC) - (.063 * Trip\ plan).$$