International Journal of Automotive Research, Vol. 9, No. 4, (2019), 3125-3131

Iran University of Science and Technology

International Journal of Automotive Engineering

Journal Homepage: ijae.iust.ac.ir

ISSN: 2008-9899

Environmental Impact Assessment of replacing Conventional Taxis with Hybrid Electric Vehicles in Tehran, Iran

Moein Nili Ahmadabadi[1], Pouria Ahmadi[1]*, Mahdi Soleymani[1], Seyed Alireza Atyabi[1], Mohammadjafar Hadad[1]

[1]School of Mechanical Engineering, College of Engineering, University of Tehran, Tehran, Iran

ARTICLE INFO

Article history:

Received : 02 March 2019

Accepted: 05 May 2019

Published: 01 Dec 2019

Keywords:

Electric vehicle,

LCA,

Lifecycle cost,

Lifecycle emission,

Optimization

A B S T R A C T

One of the most significant issues of recent decades is pollution and dangers that may threat the environment. Different approaches were presented to protect the environment and target various sources of pollution. Old vehicles are one of the major sources of pollution in megacities as they consume and emit a lot of emissions. Therefore governments in different countries try to levy tax on pollution to motivate people to drive environment friendly and more efficient vehicles.

Tehran is one of the cities suffering rigorously from poor air quality. As a result, approximately 44 days in each year the air quality reckons as unhealthy for all residents. One of the suggested solutions is replacing conventional taxis across the city with hybrid electric vehicles. In this article this solution for the city of Tehran, Iran will be discussed and its feasibility will be evaluated using life cycle assessment.

In order to conduct this, first data associated with air quality, pollution and taxis distribution in the city were presented. Then different designated vehicles were evaluated based on their technical performance and the emission they generate in different stages. Using the proposed model a comprehensive cost is defined and different vehicles were compared and the most viable choices by various considerations is introduced.

1. Introduction

In recent years and due to population growth, the world's major cities including Tehran, the capital of Iran, have faced environmental pollution problems. Although the limitations and various laws from government agencies could have improved this problem, still an important part of the issue remains unsolved. For instance, despite enforcement laws like the limitation of using old cars, low-emission zone and motivational plans for cars replacement, no significant progress has been made in urban air quality.

According to World Bank statistics (updated July 2 of 2013), there are about 158 motor vehicles per 1,000 people in Iran and 135 of these are cars. Despite the rules of car fuel standards and subsidies reduction for fuel prices in Iran, fuel consumption rate per car is high compared to other countries in the world. While fuel consumption in Iran is 5.4 liters per car per day, this amount is 3.5 liters in England, 2.5 liters in Germany and Japan and 1.9 liters in France. This indicates the lack of standard fuel consumption pattern in Iran, especially in urban areas.

* Corresponding Author
Email Address: Pahmadi@ut.ac.ir
http:// tlx.doi.org/10.22068/ijae.9.4.3123

[DOI: 10.22068/ijae.9.4.3123]

According to statistics released by Air Quality Control Company, 80% of air pollutants in Tehran was generated from vehicles. In gas emissions such as CO2, SO2 and NOX, carburetor vehicles play a major role. Also, 20% of this emission is related to taxi fleet across the city.

Currently based on taxi fleet information, about 80 thousand taxis are in transition and servicing in Tehran in which 91% are cars and the rest are vans. Also, Peugeot 405 and Samand have the largest share of the taxi vehicles. Fig 1 shows the distribution of urban taxis and their average life span[1].

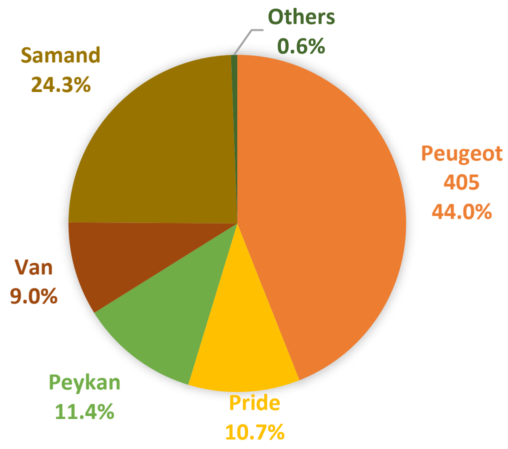

Figure 1: Distribution of Tehran urban taxis

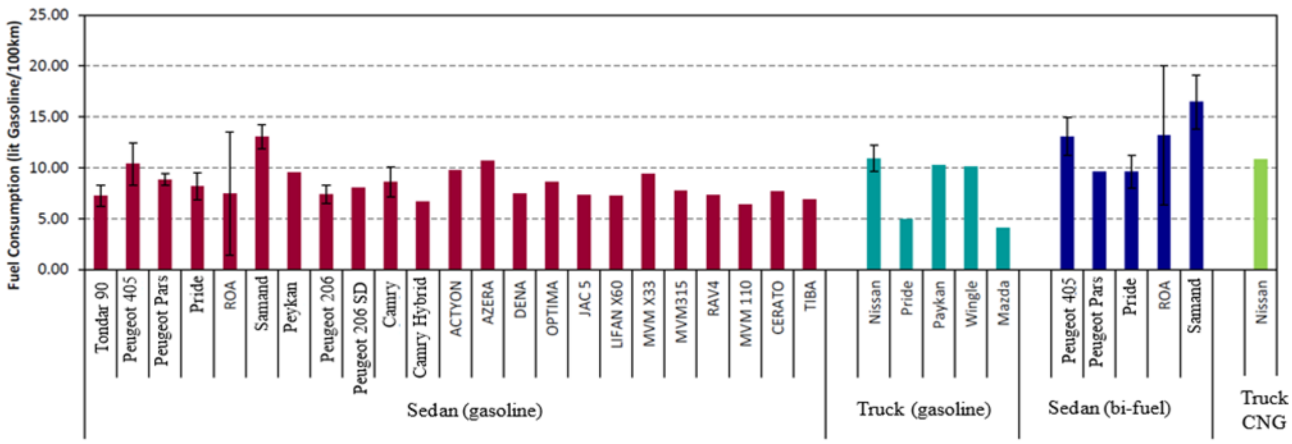

Figure 2: Fuel consumption for common vehicles in Tehran

There are about 22.6 million daily intra-city trips in Tehran per day which five million of them belong to the Taxi Department. In addition, according to the latest statistics in 2018, estimation of Tehran's traffic transport model, about 25 million trips take place in Tehran every day. Taxis and vans consist twenty percent of whole travels in a day.

The Fig 3 shows the demand and popularity of this type of transportation among the residents of the capital. However, Tehran's taxis have a significant share in fuel consumption due to being outdated and exhaustion rates. Also, the traffic control zone in the city is one of the most polluted urban areas, with an average of 10 to 14 thousand taxis that service every day. Therefore, the hybrid vehicle replacement plan can be considered as an effective solution to reduce air pollution in Tehran [2].

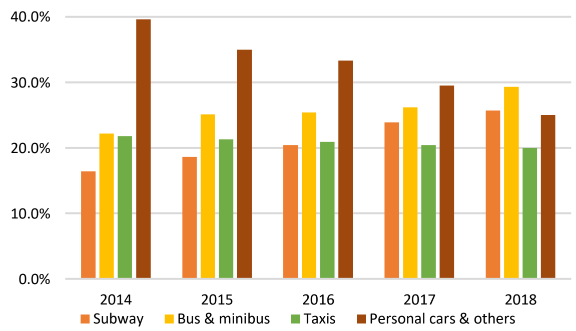

Figure 3:the contribution of different transportation modes

2. Methodology

This paper provides comprehensive information about evaluating ICEV Taxis supplant with Hybrid electric vehicle. The project involves collecting data from existing resources to extract information from the manufacturing process of the car and producing fuel to the service to the customer. The first step of this paper is collecting

[DOI: 10.22068/ijae.9.4.3123]

data associated with life cycle assessment method and proposing the desired algorithm that can satisfy the goal of the project. Furthermore, data related to the pollution in Tehran has been gathered as well as data about taxis which they have been manufactured in Iran. Information about hybrid cars that is available to buy in Iran has been also collected. Consequently, documents about emission rate of taxis and hybrid cars in various ways and paths were accumulated. Next, an all-inclusive software for replacing taxis with hybrid ones in Tehran was designed and developed and result are presented based on data. Also, a financial risk and feasibility, technical analysis and assessing Lifecycle Assessment have been done. Lifecycle assessment is a holistic approach that evaluates the environmental impacts of a product. Lifecycle assessment quantifies the impact of each component of a product on the environment from raw material extraction to its end of life1 and finally investigates the results. [3]

As mentioned for reaching the targets of the paper, essential need of plethora of data and information was obvious so all of them has been prepared from the diverse institution in Iran that will be explained. Since it was one of the goals of reducing gasoline and gas consumption, it was necessary to know the amount of fuel consumed, which, according to the data of the Tehran municipality, daily fuel consumption that can be used to approximate daily fuel consumption for taxis in the city is shown in the Table1.

Table 1 Daily fuel consumption in Tehran per million litter

Daily consumption of gasoline	10.8
Daily consumption of gas transportation specials	2.8
Daily consumption of CNG	2.14

Another crucial objective of the paper is to reduce the air pollution in Tehran, so there is a need for data on pollution in Tehran and statistical comparison between them, which is taken from the municipality of Tehran and the Meteorological Organization. Fig 4 demonstrates the air quality of Tehran in different months of the year. As it is shown, it can be clearly seen that during the cold months, Tehran's weather is in an unhealthy condition [4].

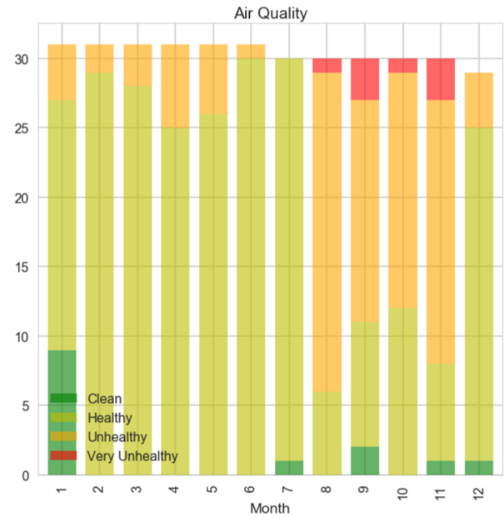

Figure 4 : Air quality of Tehran by month

Based on the results of research on the engine performance and the production of pollutants, several factors are considered as parameters affecting the severity of emissions and fuel consumption. These studies consider factors such as standard and vehicle design technology, maintenance conditions, driving behavior, road slope, environmental conditions, fuel specifications and operating status of the air conditioner as factors affecting the emission of gas from cars.

Calculation of emission factors and fuel consumption can be calculated according to the emission factor of carbon emissions as well as oxygen gas by the carbon balance method. Subsequently, in this method, if the fuel burned and the molecular concentration of carbon dioxide, carbon monoxide, oxygen, nitrogen oxides, and unburned hydrocarbons are known, the mass of each of the examples mentioned can be calculated. It should be noted that in this procedure, after determining the molar ratio of products and the total molecular weight of products, the mass of each product can be calculated. According to the above-mentioned experiments and calculations at the Sharif University of Technology, the following results are obtained.

Initially, a database was created to hold statistical information about different vehicles. Then the software was designed to be able to run on a database basis. The following is an illustration of the first section of the software.

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Vehicle	Fuel Type	Fuel Economy(lit/hkm)	Emission(Operation)	Emission(Fuel Production)	Maintenance Cost	VKT	Price($)
ICEV(Gasoline)	Gasoline	9	63.7828	268.3915	0.3200	100000	15000
ICEV(CNG)	CNG	12	90.8809	11.0469	0.6400	100000	15000
HEV	Gasoline	4	57.1432	119.2851	0.1600	100000	20000
PHEV	Gasoline	1	40.0461	29.8213	0.1600	100000	25000
405	Gasoline	14.5200	467.5992	433.0049	0.3200	100000	7400
405-CNG	CNG	14.4450	371.3468	13.2977	0.6400	100000	7700
Pride	Gasoline	11.3333	350.6077	337.9745	0.3200	100000	5200
Pride-CNG	CNG	13.0100	310.7555	11.9766	0.6400	100000	5400
Samand	Gasoline	13.9625	543.4377	416.3796	0.3200	100000	7600
Samand(CNG)	CNG	16.4975	299.2318	15.1871	0.6400	100000	7900
Camry	Gasoline	13.7100	59.9609	408.8497	0.3200	100000	17000
Camry-Hybrid	Gasoline	6.6150	21.7831	197.2677	0.1600	100000	20000
Prius	Gasoline	5.8820	18.7785	175.4087	0.1600	100000	17000

Figure 5: The screenshot of the developed LCA software

For each pollutant, a price has been set that uses global data for this purpose. The price list for each of the pollutants is as follows:

In calculating the number of pollutants used in the table above to convert pollutants to each other, for example, each kilogram of PM 2.5 is equivalent to 5760 kg of CO_2. Ultimately, all pollutants are converted to CO to provide better reporting to the user.

Table 2: Price of each pollution for each ton

pollutant	Price($ per tons)
VOC	3400
CO	6424
NOx	9750
PM10	18600
PM2.5	155500
SOx	12500
CH4	918
CO2	27
N2O	8046

3. Results

After conducting research on air quality of Tehran and the significant role that taxis play in it and gathering data associated with it, a model presented and it is used to estimates the comprehensive price of each vehicle based on life cycle assessment. The comprehensive price consists of the car price, cost of maintenance, tax on pollution in different stages, and fuel costs.

The first result that rendered by the designed software is the amount of pollution based on a kilometer distance that each car traveled. Fig 6 shows the amount of pollution and share of each particle.

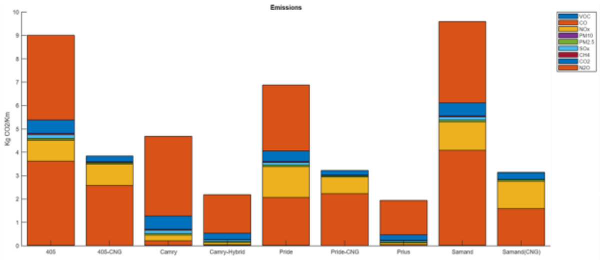

Figure 6 : Vehicle emissions by contaminants

Pollution is created in two different sections which Fig 2 shows it for each car. The blue sections denote to the pollution which generated in the process of fuel production and Red sections illustrate the pollution that generated in vehicle operation.

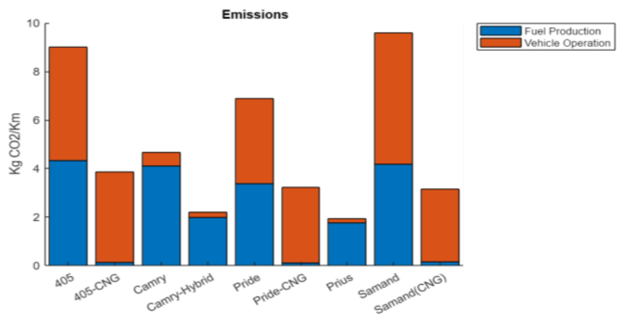

Figure 7 : Vehicle emissions in each stage

As it is shown in Fig 6&7 hybrid vehicles have the least pollution and conventional gasoline vehicles generate the most amount of pollution. Figures also show that CNG is a better choice compared to gasoline because the process of producing it is much cleaner.

Also, pollution which is caused as a result of vehicle operation is considerably higher for vehicles that manufactured in Iran compared to imported cars.

After presenting emissions it is important to utilize the mentioned algorithm to find the most

[DOI: 10.22068/ijae.9.4.3123]

efficient vehicle for supplant project based on life cycle assessment. Fig 8 can show the price of different vehicles excluding any taxes on pollution.

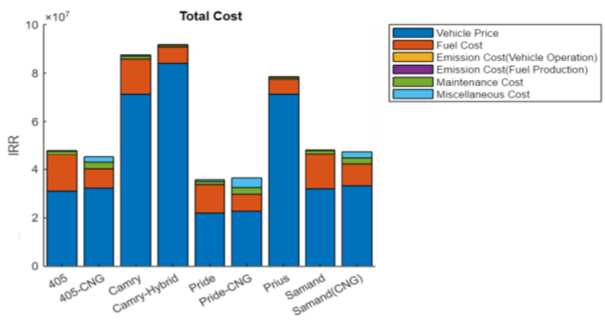

Figure 8 : Comprehensive price excluding tax

In Fig 3 the price of gasoline assumed to be 10000 IRR per liter and 4200 IRR per cubic meter for CNG. Also, it can be comprehended that there is a meaningful difference between imported vehicles and vehicles that manufactured in Iran.

However, Fig 4 shows the effect of pollution tax on the price of different vehicles as an indicator to help the comparison between different designated cars for the project.

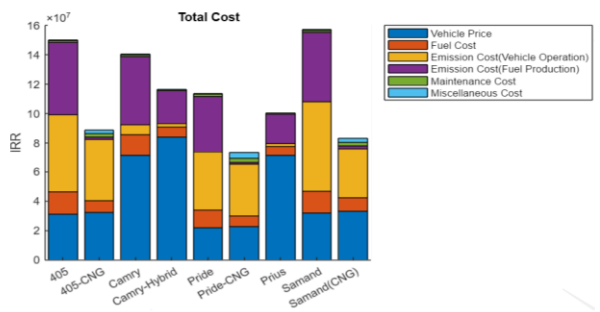

Figure 9 : Comprehensive price including tax

As it is shown in Fig 9 while hybrid vehicles have more initial cost eventually they can be a more efficient choice compared to cars with gasoline fuel based on LCA.

By increasing the price of fossil fuels and getting closer to the real price, it can be seen in Fig 5 that how it can affect the comprehensive price of each vehicle.

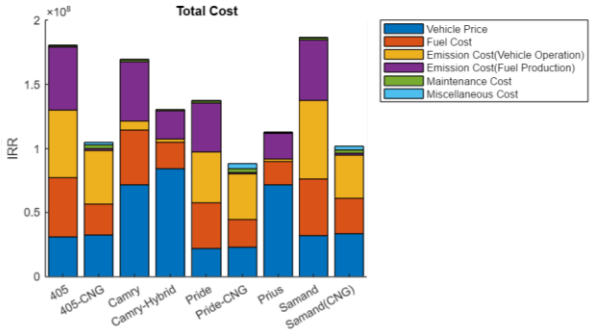

Figure 10 : Comprehensive price including tax

In Fig 10 the price of gasoline is assumed to be 30000 IRR per liter and 12000 per cubic meter for CNG.

In the next step, it is crucial to conclude the presented result by evaluating the financial balance for replacing all taxis across the city with each nominated vehicle.

In order to proceed, it is necessary to have several assumptions based on the presented distribution of taxis in Tehran.

As mentioned most of the taxis in Tehran are bi-fuel vehicles (consuming both gasoline and CNG). Therefore it is reasonable to presume that these vehicles only use gasoline while they are operating as a taxi across the city.

Using comprehensive cost for all taxis which is generated as a result of taxis distribution in the city it is convincing that the plan can decrease the pollution and costs simultaneously after the replacement. Also, in order to evaluate the comprehensive economic evaluation, a financial balance has been defined which positive balance denotes conserving in costs and a negative one means the plan needs an excess financial budget. Results are presented in table 3.

In the emission column, red numbers mean that the amount of pollution may increase if the presented car selects.

The table illustrates that it is necessary to supplant taxis with hybrid vehicles in order to minimize pollution. Also, financial evaluations show that if the price for gasoline raises up to 20000 IRR and for gas increases up to 8400 IRR and based on the mentioned tax on pollution, replacing all of the taxis in the city with Toyota Prius is completely affordable.

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As it is obvious there is not any specific correlation between the amount of pollution and the price of a vehicle. Therefore the importance of each one is upon the goal of the project. For example in the cold season as a result of air inversion phenomena, the pollution in the city reaches an alarming situation. Thus minimizing the pollution is significantly important. However in the spring as a result of clear air, the importance of pollution diminishes.

Thus because of simplicity in making the correct decision, a tradeoff coefficient has been defined. The following formula is presented to serve the purpose:

$$OF = w \times \frac{Emission}{Emission_{max}} + (1-w) \times \frac{Cost}{Cost_{max}}$$

$$(0 < w < 1)$$

Table 2 Financial balance based on vehicle selection for the supplant project

Fuel Cost		Gasoline:1000 CNG:400	Gasoline:2000 CNG:800	Gasoline:3000 CNG:1200
Vehicle	CO_2 Emission Decline(kt)	Financial Balance($\times 10^9$)		
405	-26820.00	-3310.86	-3757.32	-4204.20
405-CNG	6263.00	743.40	885.78	1027.74
Pride	-13220.00	-974.82	-1206.66	-1438.50
Pride-CNG	10230.00	1732.50	1913.10	2094.12
Samand	-30610.00	-3758.16	-4167.24	-4578.00
Samand(CNG)	10770.00	1124.34	1211.28	1298.22
Camry	866.90	-2702.28	-3094.56	-3486.42
Camry-Hybrid	16880.00	-1160.04	-1074.36	-988.68
Prius	18470.00	-126.63	8.44	143.51

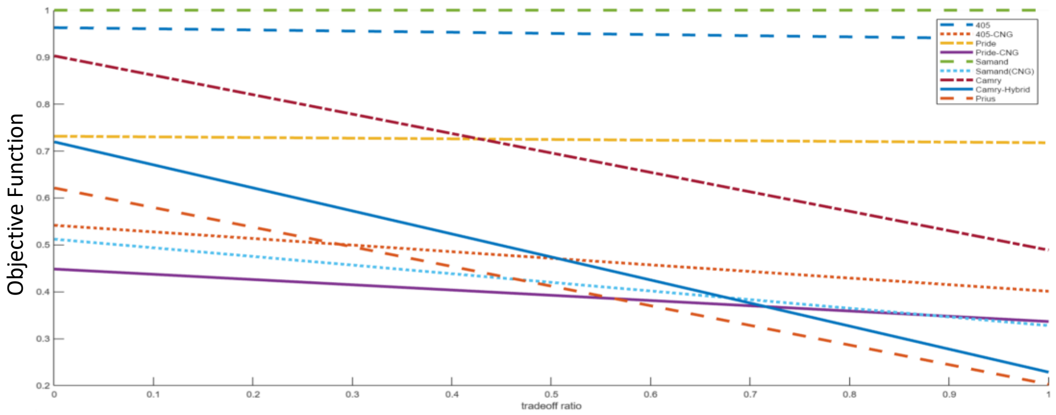

Figure 11. Trade-off coefficient's effect on each vehicle

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The equation is a linear relation that by increasing the w up to 1 the importance of the pollution reaches the highest and the cost loses its value. On the other hand, by decreasing the w to 0 the result will be inverted and the pollution loses its importance. Therefore the optimum vehicle by each desired w is the one that associated with the lowest objective function. Fig 11 can show results for each selected vehicle for all w in the range.

As it is demonstrated in Fig 11 when the pollution is the most important factor Hybrid vehicles are favorite choices because the acquired the minimum value of the objective function. Toyota Prius can be the best possible choice and after that, Camry hybrid has the advantage.However, when the price is the crucial factor vehicles that consume CNG fuel can be the best choices for the supplant project. Because when w gets closer to zero the objective function for CNG based vehicles shows the lowest value.

4. Conclusion

Taxis in Tehran play a significant role in air quality and therefore it is vital to replace other vehicles that can both perform as a taxi and reduce the pollution in the city. The supplant project can be very expensive thus it is crucial to choose the most efficient plan that can simultaneously minimize the cost and reduce the pollution associated with taxis.

In this article, it was proved that changing current taxis with hybrid vehicles can satisfy both goals if certain taxes levies on pollution which is generated during different stages and also the price of gasoline and CNG get double. Also, choosing each subsequent car is mostly upon the policy maker. Because the relationship between cost and pollution can be defined differently based on the situation.

Future research should target other sources of pollution in the city such as trucks and motorcycle. The introduced method and the software can easily be modified to estimate the comprehensive cost and life cycle assessment for other sources of pollution as well.

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[DOI: 10.22068/ijae.9.4.3123]