ECONOMIC ANALYSIS OF APPLICATION OF DIFFERENT DRIVE TRAINS IN VEHICLES

Ivan Grujić[1], Aleksandar Davinić, Nadica Stojanović, Dragan Taranović, Radivoje Pešić

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ABSTRACT: Vehicles are considered to be the biggest polluters of the environment. An alternative to conventional vehicles are hybrid and electric vehicles. Despite the good qualities of these vehicles, they can rarely be seen on the roads. In this paper, economic analysis is performed in order to determine cost effectiveness of the application of these types of vehicles. A comparison between the costs of owning a hybrid, conventional and electric vehicle is considered, in order to determine whether the costs have the greatest impact on the purchase of these vehicles. The costs included: price of a new vehicle, fuel price per km and maintenance price per km. The performed analysis shows that hybrid and electric vehicles do not have better economic indicators than vehicles with IC engines.

KEY WORDS: hybrid, conventional, electric, vehicles, costs, analysis

EKONOMSKA ANALIZA PRIMENE RAZLIČITIH POGONA U VOZILIMA

REZIME: Vozila se smatraju najvećim zagađivačima okoline. Alternativa konvencionalnim vozilima su hibridna i električna vozila. Uprkos dobrim osobinama ovih vozila, retko se mogu videti na putevima. U ovom radu, izvršena je ekonomska analiza kako bi se utvrdila isplativost primene ovih tipova vozila. Urađeno je poređenje između troškova posedovanja hibridnog, konvencionalnog i električnog vozila, u cilju utvrđivanja da li troškovi imaju najveći uticaj na kupovinu ovakvih vozila. U troškove su uključeni cena novog vozila, cena goriva po km i cena održavanja po km. Izvršena analiza pokazala je da hibridna i električna vozila nemaju bolje ekonomske pokazatelje od vozila sa motorom SUS.

KLJUČNE REČI: hibridno, konvencionalno, električno, vozila, troškovi, analiza

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1. INTRODUCTION

The development of combustion engines, especially vehicle engines, is one of the greatest achievements in technology. More precisely, a life without a vehicle is impossible today. This is because vehicles have a major role in everyday life of modern society. In addition, vehicle production has a big influence on the world economy. It is best explained by an increasing trend of numbers of light duty vehicles in the world, shown in Figure 1. The everyday increase of number of vehicles, unfortunately, has a negative effect, such as air pollution and higher fuel consumption. This kind of problem created a need to produce vehicles that are less polluting and have a lower fuel consumption. One of the best choices of vehicles is a hybrid electric vehicle. Despite their good qualities, the hybrid vehicles are rarely seen on the road [1]. Why does this happen? One of possible answers is the existence of opinion that these vehicles are expensive to own.

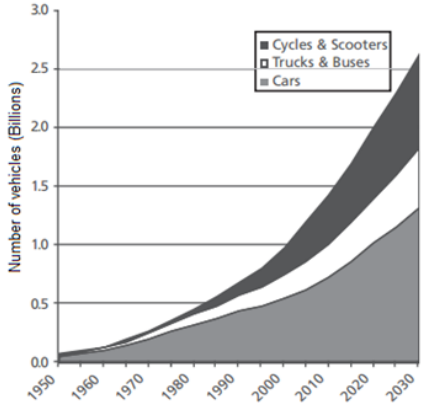

Figure 1 Global growth of vehicles [2]

[1] *Ivan Grujić, M.Sc., assist., University of Kragujevac, Faculty of Engineering, 6 Sestre Janjić Str., 34000 Kragujevac, Serbia, ivan.grujic@kg.ac.rs*
[2] *Aleksandar Davinić, Ph. D., assist. prof., University of Kragujevac, Faculty of Engineering, 6 Sestre Janjić Str., 34000 Kragujevac, Serbia, davinic@kg.ac.rs*
[3] *Nadica Stojanović, M.Sc., assist., University of Kragujevac, Faculty of Engineering, 6 Sestre Janjić Str., 34000 Kragujevac, Serbia, nadica.stojanovic@kg.ac.rs*
[4] *Dragan Taranović, Ph. D., assist. prof., University of Kragujevac, Faculty of Engineering, 6 Sestre Janjić Str., 34000 Kragujevac, Serbia, tara@kg.ac.rs*
[5] *Radivoje Pešić, Ph. D., prof., University of Kragujevac, Faculty of Engineering, 6 Sestre Janjić Str., 34000 Kragujevac, Serbia, pesicr@kg.ac.rs*

The main purpose of this paper is to conduct the cost-effectiveness analysis of buying and owning vehicles with different drive trains. In order to perform the cost-effectiveness analysis, data on costs of buying and owning vehicles with different drive trains are necessary.

2. RESEARCH METHOD AND MATERIALS

The best method for this type of the analysis is a statistical method. Data needed for statistical analysis in this paper are taken from [3]. The basic idea of the research is to compare the costs of ownership of hybrid, conventional and electric vehicles. Six vehicles were used in research, two for each type of drivetrain. The first group of vehicles used in analysis consists of: Toyota Yaris 1.3 (conventional), Toyota Prius 1.5 (hybrid) and Nissan Leaf (electric), Figure 2. The second group contains more luxury vehicles then vehicles from the first group. Vehicles from the second group are: Nissan Qashqai 2.0 (conventional), Toyota Prius 1.8 (hybrid) and Holden Volt (electric), Figure 3.

a) Toyota Yaris 1.3

b) Toyota Prius 1.5

c) Nissan Leaf

Figure 2 Vehicles used for research [4, 5, 6]

a) Nissan Qashqai

b) Toyota Prius 1.8

c) Holden Volt

Figure 3 Vehicles used for research [7, 8, 9]

Table 1 Price values in $ [3]

	Price of a new vehicle (*PNV*)	Fuel price per km (*FP*)	Maintenance price per km (*MP*)
Toyota Yaris 1.3	16,490	0.0819	0.0807
Toyota Prius 1.5	22,990	0.055	0.0945
Nissan Leaf	34,200	0.0483	0.0709
Nissan Qashqai 2.0	28,490	0.0897	0.0634
Toyota Prius 1.8	32,490	0.055	0.0967
Holden Volt	59,990	0.0546	0.0574

Based on prices given in Table 1, the analysis of ownership costs for 75,000 km (P_{75000}) and 150,000 km (P_{150000}) travelled by vehicle is performed and difference between these values (PD) is calculated:

$$P_{75000} = PNV + (FP + MP) \cdot 75000 \quad (1)$$

$$P_{150000} = PNV + (FP + MP) \cdot 150000 \quad (2)$$

$$PD = P_{150000} - P_{75000} \quad (3)$$

In addition, according to data from Table 1, analysis of ownership costs per year (PPY) is conducted, assuming that the vehicle travels 50,000 km per year. For this calculation, the next equation is used.

$$PPY = PNV + (FP + MP) \cdot 50000 \cdot NY \quad (4)$$

3. RESULTS AND DISCUSSION

By using data from Table 1, and equations (1) to (3), the following data are obtained and presented in Table 2.

Table 2 Costs of ownership for 75,000 km and 150,000 km and difference of costs in $

	P_{75000}	P_{150000}	PD
Toyota Yaris 1.3	28,685	40,880	12,195
Toyota Prius 1.5	34,202.5	45,415	11,212.5
Nissan Leaf	43,140	52,080	8,940
Nissan Qashqai 2.0	39,972.5	51,455	11,482.5
Toyota Prius 1.8	43,867.5	55,245	11,377.5
Holden Volt	68,390	76,790	8,400

Data from Table 2 can be better analyses observing the Figure 4 (for the first group of vehicles) and Figure 5 (for the second group of vehicles), where ownership costs after 75,000 km travelled are presented.

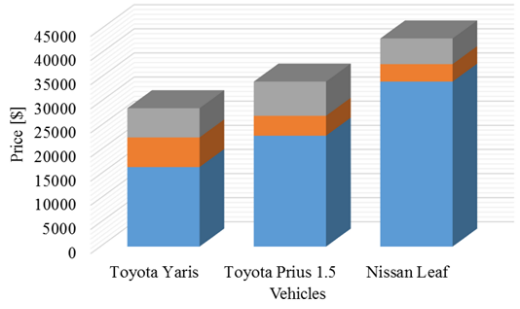

Figure 4 Costs of ownership (the first group of vehicles) for 75,000 km travelled

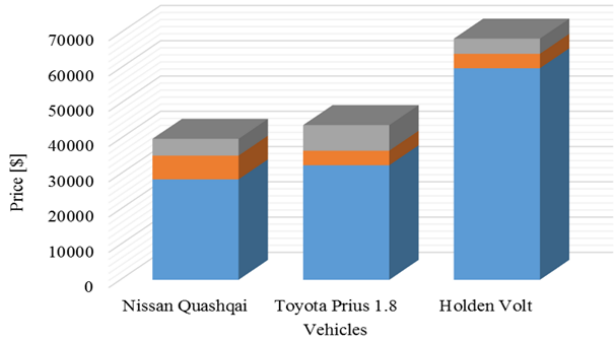

Figure 5 Costs of ownership (the second group of vehicles) for 75,000 km travelled

By analysis of data from Figures 4 and 5, it can be seen that the most expensive vehicle to own is the electric vehicle. The reason is a high price for a new vehicle. Hybrid vehicle is the most expensive to maintain because of the two types of drivetrain. In addition, it can be seen that the hybrid vehicle is still more expensive to own after 75,000 km travelled than conventional vehicle. Also, from Table 2, it can be seen that after 150,000 km travelled, the vehicle with conventional drive train is still cheaper than vehicles with other types of drive trains.

In addition, calculations were performed in order to see how many kilometres the hybrid or electric vehicle needs to travel to be less expensive than vehicle with conventional drive train. Boundaries are set at vehicles traveling 50,000 km per year. Analysis is performed for a period of 10 years. Results are given in Tables 3 and 4 and Figures 6 and 7.

Table 3 Costs of ownership through years in $ (the first group of vehicles)

Distance travelled [km]	Toyota Yaris	Toyota Prius 1.5	Nissan Leaf	Time [years]	Toyota Yaris	Toyota Prius 1.3	Nissan Leaf
Vehicle price	16490	22990	34200				
1	0.1626	0.1495	0.1192				
50,000	8,130	7,475	5,960	1	24,620	30,465	40,160
100,000	16,260	14,950	11,920	2	32,750	37,940	46,120
150,000	24,390	22,425	17,880	3	40,880	45,415	52,080
200,000	32,520	29,900	23,840	4	49,010	52,890	58,040
250,000	40,650	37,375	29,800	5	57,140	60,365	64,000
300,000	48,780	44,850	35,760	6	65,270	67,840	69,960
350,000	56,910	52,325	41,720	7	73,400	75,315	75,920
400,000	65,040	59,800	47,680	8	81,530	82,790	81,880
450,000	73,170	67,275	53,640	9	89,660	90,265	87,840
500,000	81,300	74,750	59,600	10	97,790	97,740	93,800

Table 4 Costs of ownership through years in $ (the second group of vehicles)

Distance travelled [km]	Nissan Qashqai 2.0	Toyota Prius 1.8	Holden Volt	Time [years]	Nissan Qashqai 2.0	Toyota Prius 1.8	Holden Volt
Vehicle price	28490	32490	59990				
1	0.1531	0.1517	0.112				
50,000	7,655	7,585	5,600	1	36,145	40,075	65,590
100,000	15,310	15,170	11,200	2	43,800	47,660	71,190
150,000	22,965	22,755	16,800	3	51,455	55,245	76,790
200,000	30,620	30,340	22,400	4	59,110	62,830	82,390
250,000	38,275	37,925	28,000	5	66,765	70,415	87,990
300,000	45,930	45,510	33,600	6	74,420	78,000	93,590
350,000	53,585	53,095	39,200	7	82,075	85,585	99,190
400,000	61,240	60,680	44,800	8	89,730	93,170	104,790
450,000	68,895	68,265	50,400	9	97,385	100,755	110,390
500,000	76,550	75,850	56,000	10	105,040	108,340	115,990

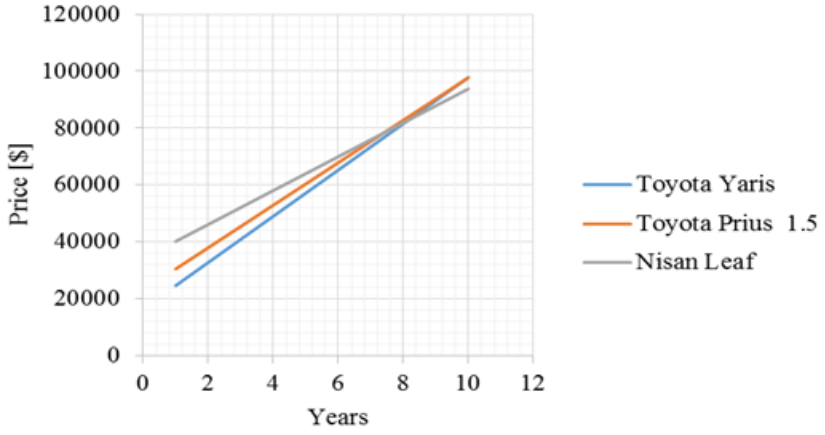

Figure 6 Costs of ownership through years (the first group of vehicles)

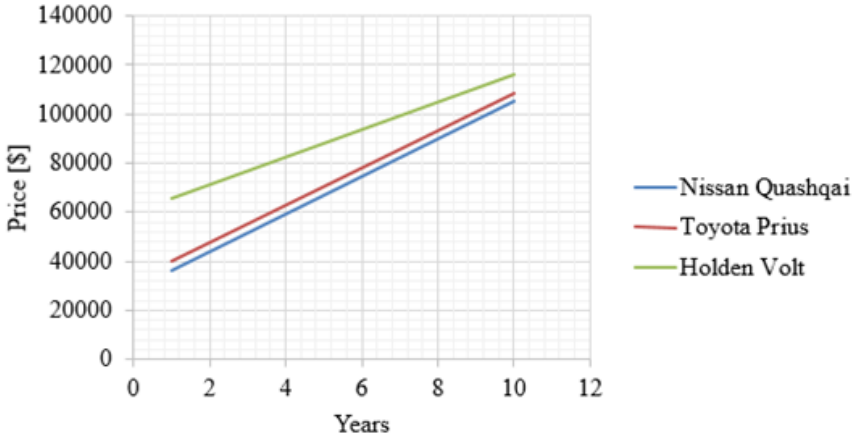

Figure 7 Costs of ownership through years (the second group of vehicles)

By analysis of Figure 6, it can be seen that the hybrid and electric vehicles have more cost effectiveness after 7 years, but if we take into account that vehicle travels over 350,000 km during this time, that is not good. Figure 7 shows that the vehicle with conventional drive train is more cost-effective even after 10 years.

4. CONCLUSIONS

Eclectic and hybrid vehicles are not something new, but strict laws have begun to impose their re-use. Despite the good qualities of these vehicles, they are rarely seen on the road. The main reasons are the costs of ownership. Based on performed analyses, these types of vehicles do not have better economic indicators than conventional vehicles. In one case (the first group of vehicles) these types of vehicles have better economic indicators after 350,000 km travelled, but this is a very big number. On the other hand, the hybrid and electric vehicles are friendlier to environment. There is a need to motivate people in some way to buy vehicles with these types of drive trains. The good way to achieve this is for states to give some benefits for citizens that are driving these types of vehicles, one of which may be the lower taxes for hybrid vehicles.

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