THE RISK ECONOMIC APPLICATION OF HYBRID VEHICLES

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Abstract

This paper presents an economic analysis of different introduction strategies, as well as different elements thereof, for different kinds of hybrid vehicles. A cost-benefit analysis is undertaken for increasing the number of various kinds of hybrid vehicles in the Serbian transport sector. We also analyse city-based hybrid delivery trucks, which seem to have an even larger potential profitable.

Key words

risk economic, cost-benefit analysis, hybrid vehicles

Introduction

The development of risk management started only a few years ago and certain phases of the management are still being studied. Current standards differently define and explain phases of the risk management, which creates space for use in different modalities. That is why we need to develop a systematic approach that would be used in risk management.

Considering the important role of hybrid vehicles (HVs) in transport and for the environment in most industrialised countries, it is somewhat surprising that few cost-benefit analyses (CBA) have been undertaken. Tehere are in practice many types of HVs which can be broadly categorised into two main types of HVs: hybrid gasoline vehicles (HGVs), which use gasoline as the “primary” energy, and hence is independent of central electricity production, and hybrid battery vehicles (HBVs), which are used as a battery electric vehicles (BEV) most of the time, and which also largely uses centrally produced electricity as primary energy, but which has a combustion engine largely as an auxiliary engine in order to increase performance and driving distance. In this paper we will focus on HGVs since it is more likely that they will become socially beneficial. However, for comparison we report some results for HBVs as well. Further, from the perspective of car manufacturers, there seems to be much more activity on HGVs compared to HBVs. Cars such as Toyota Prius and Honda Insight that already are at the market are indications of this.

We undertake a partial and full CBA. In the partial CBA we simply calculate the net benefit of a switch of one driven vehicle kilometre (vkm) from conventional vehicles to an HV. In the full CBA we then include the costs infrastructures.

1. Production costs for different vehicles

V70. For HGVs, characteristics and incremental price are presented in Table 1; the for the comparisons is instead a Volvo

Table 1 Characteristics and incremental price for a small HGVs relative to a comparable gasoline car

Characteristics cars	Conventional car	Mild hybrid	Advanced hybrid
Weight	1290	1320	1340
Test weight	1418	1475	1475
Drag coefficient	0,28	0,28	0,28
Tire	0,008	0,008	0,008
Engine type	2,5L I-4	1,8L I-4	1,6L I-4
Motor power, *kW*	112	90	70
Elec. motor, *kW*	None	12	30
Valves	4 s VVT	4 s VVT	4 s VVT
Transmission	5-spd man.	5-spd man.	Elect. CVT
Axle ratio	3,73	3,27	3,27
City FC, *l/100km*	8	6,5	5,34
Highway FC, *l/100km*	5,3	5,2	4,8
Composite FC, *l/100km*	6,8	5,95	5,1
Battery	-	1 *kWh*, 12 *kW*	2,5 *kWh*, 30 *kW*
Incremental price, €	base	2197	4225

Tabele 2 presents the characteristics and prices for hybrid diesel trucks (HDTs), compared to conventional diesel trucks.

Table 2 Characteristics and incremental price for conventional and hybrid diesel truck*s*

Characteristics trucks	Conventional trucks	HDTs mild hybrid	HDTs advanced hybrid
Gross weight, *tons*	12	12	12
Payload, *tons*	6,5	6,5	6,2
Engine power, *kW*	165	125	125
Engine type	6L I-6 diesel	4L I-4 diesel	4L I-4 diesel
Elec. motor, *kW*	None	40	125
Generator, *kW*	None	None	90
Battery	None	6 *kWh*, 40 *kW*	12 *kWh*, 80 *kW*
Pure BEV range	None	None	12 to 15 *km*
Fuel cons., *l/100 km*	28	22,5	20,2
Incremental price, €	base	7575	28270

2. Emission factors

The envronmental costs associated with different types of vehicles constitute an important part of our analysis. There are two important components: the emissions associated with different vehicles, and the valuation of these emissions.

For the emissions factors for gasoline and diesel vehicles we use the estimates by Ahlvik et al. (1996). These are estimated average emission factors, during the lifetime of a car of a certain vintage, based on many sources including decided emission standards within the EU. Factors such as increasing emission with age of the vehicle and cold-start effects are accounted for. We assume that emission factors for HGVs are 50% of the emission factors for gasoline cars (except for CO_2 where emissions are proportional tothe fuel use, implying about 75% of the emission factors for gasoline cars); for HBVs we assume the emissions factors (except for CO_2 and indirect emissions from electricity production) are 20% of the emission factors for gasoline cars.

Table 3 Estimated emission factors for vehicles of different vintages

Vintage	VOC, *g/km*	NO_x, *g/km*	Particles-Pm, *mg/km*
Passenger cars, gasoline (city)			
1995	1,87	0,34	7
2005	0,81	0,09	3
Passenger cars, diesel (city)			
1995	0,27	0,82	63
2005	0,12	0,28	27
Passenger cars, hybrid gasoline (mild)			
1995	0,45	0,13	6,5
2005	0,19	0,04	2,6
Passenger cars, hybrid gasoline (advanced)			
1995	0,22	0,07	3,25
2005	0,1	0,02	1,3
Trucks, diesel			
1995	0,72	9,7	200
2005	0,3	4,9	100

3. Noise costs

Unfortunately, there is very little done on estimating the external noise cost per km for different vehicles, under varying circumstances. Still, we know that hybrid vehicles, are less noisy than gasoline and diesel vehicles, and ignoring these differences would obviously bias the CBA estimates.

Table 4 Assumed external noise costs from different vehicles, €/100 km

Different vehicles	External cost, €/100km
Gasoline or diesel passenger cars	0,6
HBV	0,2
HGV (mild)	0,4
HGV (advanced)	0,4
Diesel truck	6
HDT (mild)	3
HDT (advanced)	3

4. Willingness to pay for non-conventional vehicles

For HGVs and HDTs we assume that the only difference from a standard gasoline vehicle is the gasoline consumption, and that a car buyer is indifferent between the two types of vehicles when the price difference between them is equal to the difference in expected cost of gasoline use. We assume an expected life-length of 17 years for all vehicles.

For HGVs (mild) the difference in gasoline consumption is (6,8-5,95)·150=144 litres per year and for the HGVs (advanced) the difference is (6,8-5,1)·150=255 litres per year (assuming an average driving distance of 15000 kilometres per year). With a fixed real gasoline price of 1€, this implies that the present value of the cost savings is 17·144·1=2448€ and 17·255·1=4335€ respectively.
For HDTs (mild) the difference in diesel consumption is (28-22,5)·300=1650 litres per year and for the HDTs (advanced) the difference is (28-20,2)·300=2340 litres per year (assuming an average driving distance of 30000 kilometres per year). With a fixed real diesel price of 0,8€, this implies that the present value of the cost savings is 17·1650·0,8=22440€ and 17·2340·0,8=31824€ respectively. These cost savings have to be compared with the estimated incremental prices for each vehicle (see table 1 and 2).

Table 5 Consumer surplus (CS) used in the CBA, €

Different vehicles	CS (cost saving-incremental price)
HGV (mild)	2448-2197=251
HGV (advanced)	4335-4225=110
HDT (mild)	22440-7575=14865
HDT (advanced)	31824-28270=3554

5. External costs per distance unit

Given the discussion above we can calculate the environmental cost per 100 km for the different types of vehicles. The results are reported in tabeles 6 and 7.

Table 6 Estimated external environmental costs for passenger cars, €/100 km

Local env. costs	Regional env. costs	Base CO_2	High CO_2	Noise	Env. costs base CO_2	Env. costs high CO_2
Gasoline passenger cars						
0,18	0,08	0,59	2,35	0,6	1,45	3,2
Diesel passenger cars						
1,15	0,04	0,51	2,01	0,6	2,3	3,8
HBV						
0,03	0,03	0,25	1	0,2	0,51	1,26
HGV (mild)						
0,07	0,02	0,52	2,05	0,4	1,01	2,54
HGV (advanced)						
0,03	0,01	0,45	1,76	0,4	0,89	2,21

We can see that the environmental costs generally increase drastically when the larger CO_2 valuation is used.
For passenger cars we see that diesel cars have higher associated environmental costs compared to gasoline cars. The difference is largely due to higher emissions of particles, which in turn are considered the most important emissions from a human health perspective. Diesel cars have typically lower CO_2 costs, but this difference is perhaps smaller than one might think when simply comparing fuel consumption in litre/km. First, diesel has a higher energy content per litre and, second, diesel causes higher CO_2 emissions per energy unit as well.

For trucks the local environmental costs, particularly in larger cities, are assumed to be substantial, largely due to pariculate emissions but also noise. We see that noise costs contribute largely to the environmental costs and that the CO_2 valuation case.

Table 7 Estimated external environmental costs for city trucks, €/100 km

Local env. costs	Regional env. costs	Base CO_2	High CO_2	Noise	Env. costs base CO_2	Env. costs high CO_2
Diesel trucks						
5,28	1,37	2,82	11,15	6	15,47	23,79
HDT (mild)						
2,23	0,58	1,87	7,37	3	7,67	13,17
HDT (advanced)						
2,23	0,58	1,73	6,84	3	7,54	12,64

6. Partial cost-benefit analysis

Partial costs-benefit analysis includes only the effects on the environment. The results are reported in tabeles 8 and 9.

Table 8 Net benefit in €/100 km of replacing a gasoline passenger car by a HV

Environmental benefit low CO_2	Environmental benefit high CO_2
HGV (mild)	
1,45-1,01=0,44	3,2-2,54=0,66
HGV (advanced)	
1,45-0,89=0,56	3,2-2,21=0,99
HBV	
1,45-0,51=0,94	3,2-1,26=1,94

Table 9 Net benefit in €/100 km of replacing a diesel truck by a HDT

Environmental benefit low CO_2	Environmental benefit high CO_2
HDT (mild)	
15,47-7,67=7,8	23,79-13,17=10,62
HDT (advanced)	
15,47-7,54=7,93	23,79-12,64=11,15

7. Full cost-benefit analysis

In addition to the cost and benefit components included in the last sub-section, we include here the consumer surplus (CS) and infrastructure investments needed. In CBA we assume that the average driving distance is 15000 kilometres per year for each vehicle, and that all replaced vehicles are gasoline cars or diesel trucks and bus. For trucks and bus we assume that the average driving distance is 30000 kilometres. The results are reported in tabeles 10 and 11.

Hybrid vehicles, on the other hand, are much more promising. We focus on hybrids that are not grid-charged, since grid-charged. Further, their performance compared to various kinds of HGVs is expected to be inferior. We see that the most basic kind, denoted mild HGVs, which will never be driven as a pure BEV, are generally more profitable from a social perspective than advanced HGVs, which will be powered as a pure BEV below a certain speed (e.g. 15 km/h). The mild and advanced HGV are profitable (tabele 10).

Table 10 Annual social net benefit of replacing a gasoline passenger car by a HGVs, €

	HGVs (mild)		HGVs (advanced)	
	Low CO_2	High CO_2	Low CO_2	High CO_2
Environmental benefit	0,44·150·17= 1122	0,66·150·17= 1683	0,56·150·17=1351	0,99·150·17= 2524,5
CS	251	251	110	110
Total	1373	1934	1461	2634,5

Tabele 11 provides the results for hybrid trucks, of which the advanced type is possible to grid-charge, and hence is possible to use as a pure BEV truck for shorter distances. Nevertheless, despite better environmental performances with respect to local and regional pollutants, the mild HDT is profitable.

Table 11 Annual social net benefit of replacing a diesel truck by a HDT (mild), €

	HDT (mild)		HDT (advanced)	
	Low CO_2	High CO_2	Low CO_2	High CO_2
Environmental benefit	7,8·300·17= 39780	10,62·300·17=54162	7,93·300·17= 40443	11,15·300·17 =56865
CS	14865	14865	3554	3554
Total	54645	69027	43997	60419

Conclusions

There are also issues worth reflecting on which that are normally not part of a conventional CBA, but which may nevertheless be important from a social welfare point of view. For example, technological path dependency is obviously a crucial phenomenon in the history of development of cars, and of engines in particular. Indeed, if starting from scratch with each possible technology today, it seems very unlikely that such an odd and complicated technology such as Otto-engine would even be considered to be a reasonable option. Still, we do not start from scratch, and billions of dollars have been put into the development of this peculiar technology.

Hence, trying to affect the path to an overall more beneficial one by “creating the market” for HVs seems very difficult, and it is possible that some policy makers (and others) have been overly optimistic in this respect. Still, there is of course a social value of knowledge with respect to different technologies etc, e.g. since we do not know which technologies that will survive and develop in a few decade perspectives.

References

[1] GREENE D. L., JONES D.W.: The Full Costs and Benefits of Transportation, Heidelberg, 2000.

[2] HARROP P., HARROP G.: Electric Vehicles are Profitable: Where, Why, What, Next?, Footnote publications, Hampshire, UK, 1999.

[3] EWING G., SARIGOLLU E.: Car fuel-type choice under travel demand menagement and economic incentives, Transportation Research, 1998.

[4] BACKSTROM S.: Environmental Assessment of Energy Supply Chains for Electric Propelled Road Traffic, Report to KFB, 1998.

[5] AHLVIK P., LAVESKOG A.: Emissions faktorer for fordon drivna med biodrivmedel, Motortestcenter (MTC) vid AB Svenks Bilprovning, Stockholms Universitet, Svensk, 1996.
[6] www.ekoserb.sr.gov.yu
[7] www.mntr.sr.gov.yu/mntr
[8] www.amss.org.yu
[9] www.bilweb.se

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