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# Human Society Viewed from the Perspective of 3R-Eco Activities and Environmental Measures: Part I -Effectiveness of Incorporating the Hybrid System into Low Fuel-efficient and Long-distance Automobiles-

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**Abstract** There is increasing concern over environmental issues and measures to address them across the world. In particular, 3R-Eco activities and other environmental measures have been implemented at a personal to national level. However, current environmental measures are not necessarily effective. To address and solve environmental issues in a real sense, it is important to keep in mind that environmental issues are problems caused by humans. Therefore, the present paper discusses them with a focus on 3R-Eco activities. This paper first discusses “Reduction (waste-reduction) activities”. Large numbers of people are involved in activities that aim to reduce gasoline consumption in particular. There are several approaches, including the combined use of bio and fossil fuels, adoption of solar cars to reduce gasoline consumption, and improving fuel efficiency. Among these, there has been marked progress in hybrid technology in recent years. However, it is still questionable whether the current utilization of hybrid vehicles and technology is an effective environmental measure in today’s society, in which people heavily rely on automobiles. In response to this question, the present study examined the effectiveness of the “use of hybrid technology” for “fuel-efficient automobiles” and “those that run long distances”, including a calculation of the gasoline consumption that can be reduced with the use of hybrid vehicles and an examination of its relationship with fuel efficiency, based on data regarding the use of automobiles by Japanese people. The results suggest the environmental measures that are effective.

**Keywords** Hybrid car, Gasoline, Fuel-efficiency, 3R, Reduce

## 1. Introduction

In recent years, the words “environment” and “eco” have been frequently used in newspapers and magazines, on TV, and by other media. Summit conferences are held by international organizations to discuss global environmental issues, and the Japanese government has established the Ministry of the Environment as a central government ministry to address environmental problems[1]. Companies develop and distribute new eco-products every year. A number of universities have faculties and departments whose names include the term “environment”. There has been an increase in the number of classes related to “environments” in compulsory education. There are also increasing numbers of environmental volunteer activities and NPOs, and many people take their own shopping bags to supermarkets, rather than use plastic bags provided by stores, as an environmental activity at a personal level. However, not all of these environmental measures are necessarily effective[2]. This is presumably due to a lack of understanding of the fact that environmental problems are attributed to human society.

Environmental issues and measures are discussed on the assumption that: national security is a mission of a country; companies aim to generate profits; schools are in charge of education; and people place the highest priority on life. The implementation of effective environmental measures based on this assumption is “an appropriate approach to environmental issues to be adopted by human society”. However, environmental measures have been influenced by ulterior motives and intentions, and become very complicated. As a result, they have often been adopted according to people’s interests and caused damage to human society. To address environmental issues, it is important to: keep in mind that environmental problems are attributed to human society; discuss the problems from various viewpoints in human society; and pay attention to the balance between human society and environmental issues. Based on this idea, the present study focused on 3R-Eco activities[3].

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Personally, we do not like the phrase “For the Earth”, an expression frequently used in descriptions of environmental issues. Even if the mean temperature rises 10°C due to global warming, the Earth itself will continue to operate. Global warming causes damage to human society, rather than the Earth. People should recognize environmental problems as those that matter to themselves, and implement effective measures “for humans”, not “for the Earth”, although it is very difficult to develop such measures.

Considering that it is “important to implement environmental measures on the basis of human society”, we discussed hybrid vehicles and reached a conclusion, although we have not yet clarified the whole picture.

With the aim of solving environmental problems in a real sense, the present study focused on existing and new eco technologies as well as their use.

## 2. Background of the Study

### 2.1. Outline of 3R-Eco Activities

The 3R-Eco activities discussed in this paper are based on the following three actions: reduce, reuse, and recycle. Most eco activities performed across the world are based on one or more of these concepts. The following are summaries of the eco activities:

<Summary of reduction-oriented eco activities>

These activities are based on efforts to “Reduce the purchase or consumption of products that may produce waste”. Eco activities performed based on this concept include taking your own bag when shopping and reducing gasoline consumption. Reduction-oriented eco activities are associated with the problem of substitute products. In this type of activity, a product is replaced by another to reduce the environmental load, and the effectiveness of the eco activity depends on what a product is replaced by; in the case of hybrid vehicles, gasoline is replaced by electricity.

<Summary of reuse-oriented eco activities>

The activities are based on the “Reuse of a product (or its repeated use), instead of purchasing a new one, no matter how old it is”. Of the three types of activity, e.g., recycle shops, this type is most closely related to the economy. Recycle shops have problems regarding economic aspects and the durability of products; despite their name, these shops are actually involved in reuse activities. As in other economic activities, if an imbalance is caused between supply and demand, when supply exceeds demand in particular, used products collected by recycle shops will be no better than garbage. If this occurs, recycle shops will not be able to continue to operate, which may lead to an increase in the illegal dumping of waste.

<Summary of recycle-oriented eco activities>

These activities are based on the idea that “Used products and waste should be turned into resources by recycling them”. They are the most common 3R-Eco activities, and include the collection of plastic bottles and cans. Recycling sounds very promising. However, it has some serious problems, which have been pointed out by several experts in recent years[4]. Some researchers suggest, from a technological point of view, that recycling increases the environmental load, and recycling methods and technologies have been questioned by others. Moreover, some people point out that recycling has stagnated across the world. Future technological progress may resolve these problems.

### 2.2. People Currently Involved in Eco Activities

Individuals and organizations are involved in the 3R-Eco and other global environmental activities using different approaches to environmental issues: 1) based on theories, 2) using technologies, and 3) through practice.

<Environmental approach based on theories>

Administrative agencies and research organizations, including universities, in Japan and other countries adopt this approach (in a broad sense), which is usually implemented on a large scale. These theories on the environment are sometimes controversial or affected by the interests of specific people. However, national environmental policies have significant influences on companies, and environmental activities are promoted in accordance with environmental policies developed by the government (e.g., “Team Minus 6%”)[5].

<Environmental approach using technologies>

Companies and research organizations involved in product development implement this approach using technologies. They contribute to addressing environmental problems by developing products associated with a reduced environmental load. Although a variety of eco products, including automobiles and photocopier paper, have been developed, the effects of these products still remain to be discussed. For example, even in the same industry, a technology of one company has less of an influence on the environment than a similar technology developed by another company (e.g., technologies for power generation).

<Approach based on environmental activities>

NPOs, volunteer groups, and individuals are involved in environmental activities. Since these are often small-scale and narrowly-defined activities, their effects tend to be small. However, as there has been increasing concern over environmental problems in recent years, the number of such activities is on the rise.

<Relationships among the three>

The three approaches to environmental issues are closely related to each other. Various forms of environmental activity are implemented by many different individuals and organizations: governments support environmental volunteers, and companies are involved in environmental activities through the development and distribution of eco products. National environmental policies sometimes conflict with the views of companies, and, therefore, coordination between them is also essential for environmental measures to be effectively implemented.

# 3. Reduction Activities Involving Hybrid Automobiles

Reduction activities, one form of the 3R-Eco activities, will be discussed first. Reduction-activities are currently being implemented to reduce the consumption of many products, including plastic bags provided by stores, gasoline, and disposable chopsticks. The number of people involved in activities to reduce the consumption of gasoline is the highest. A variety of methods are used in these activities, such as the combination of gasoline and bio-fuel, use of solar cars to reduce gasoline consumption, and improving the fuel efficiency of automobiles. In recent years, there has been marked progress in hybrid technology in particular[6,7,8]. The use of automobiles is closely related to the direction of human society. The present study examined whether the hybrid technology used in today's human (or Japanese) society is an effective environmental measure, and the approach involving hybrid automobiles that is the most effective.

## 3.1. Current Status of Hybrid Automobiles

<Status: Japan's motorization and hybrid automobiles>

The mean number of automobiles owned by one Japanese household is approximately 1.4. Although the famous phrase "One automobile for one household" was used to express the dissemination of automobiles in the past, nowadays, each member of a household often has their own automobile[9]. The number of automobiles owned by Japanese people in the 1960s was approximately 10 million, and the figure is about 80 million at present - almost eight times larger. Car rental services have also been accelerating Japan's motorization. In suburban areas, large-scale shopping malls with wide parking areas are being established since the main target is "customers visiting by car". In this context, there has also been an increase in environmental awareness concerning automobiles for personal use - ecological aspects of automobiles. Furthermore, the sharp rise in the price of gasoline has been increasing public awareness of fuel-efficient automobiles and demands for them, and led people to take notice of hybrid automobiles.

<Status: The world's view of hybrid automobiles>

At present, hybrid automobiles are primarily produced in Japan, attracting attention across the world. Although hydrogen-fueled automobiles in the U.S.A. and low-emission diesel automobiles in Europe are viewed as next-generation eco cars, they still have several problems. Therefore, hybrid automobiles developed based on the combined use of gasoline and electricity are expected to lead the automobile industry until high-quality, next-generation eco cars are developed. In recent years, automobile manufacturers have incorporated the hybrid system into various types of passenger automobile, including sedans and trucks; a hybrid compact automobile developed by Daihatsu has recently entered the market. Larger numbers of compact and light automobiles are expected to adopt the hybrid system to further increase their fuel efficiency. Hybrid automobiles are popular and sell very well in Japan, partly because they are regarded as status symbols. Consumers in Japan recognize them as "slightly expensive, but environmentally-friendly automobiles that help reduce expenditure on gasoline". The government recommends the purchase of hybrid automobiles because the achievement of the goal of $CO_2$ emission reduction stated in the Kyoto Protocol depends on the reduction of gasoline consumption. The government actually has implemented a preferential taxation system to refund those who purchase hybrid automobiles.

<Status: Mechanism of a hybrid automobile>

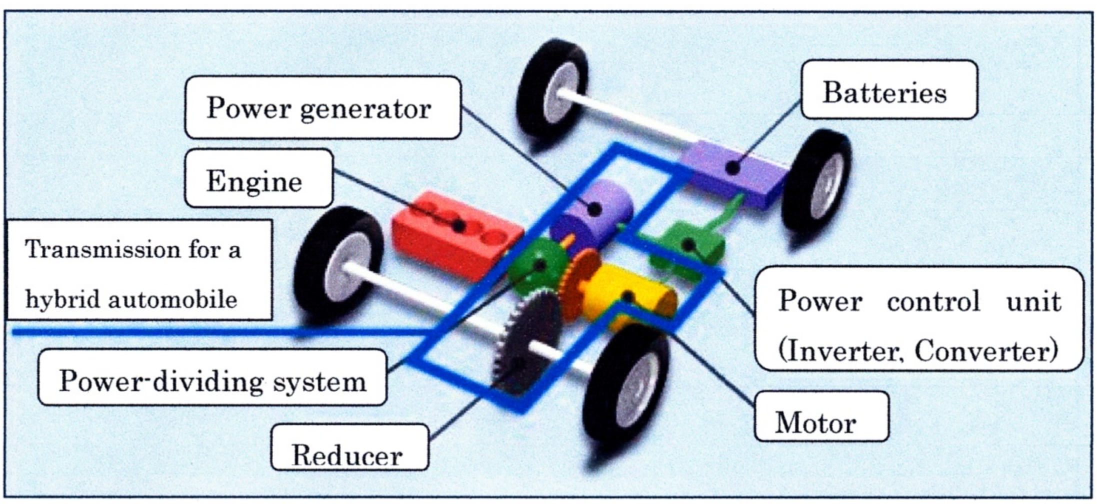


**Figure 1.** Mechanism of the Toyota Hybrid System (THS)[11]

There are various types of hybrid system, and they have made marked progress in the past few years. Although Figure 1 shows Toyota's hybrid system, there is actually little difference in the basic principle of the system among automobile manufacturers; the system is operated using an internal combustion engine and electric motor[10]. As the most notable advantage of this technology in terms of environmental protection, it utilizes waste heat from the engine to operate an electrically powered transmitter. A gasoline-fueled automobile consumes a large amount of fuel when it accelerates and decelerates, and electricity is used at this time to compensate for the fuel consumption. This can be explained from the viewpoint of physics: since less kinetic energy is required when an automobile decelerates, surplus kinetic energy is converted into heat and accumulated, which is used to operate the motor during acceleration. This system utilizes waste heat from a gasoline-fueled automobile and combines it with existing technology for motors in a sophisticated manner.

### 3.2. Validation of Hybrid Automobiles

<Theory of validation - Correlation between the costs and environmental load ->

The "correlation between the costs and environmental load" serves as an index to discuss hybrid automobiles and environmental measures. When purchasing products, most people are unaware that they are actually purchasing resources. For example, people purchasing paper are actually purchasing wood - a natural resource. This applies to the purchase of any product. In a sense, the principle of market prices, an artificial creation, is closely associated with the environmental load. To produce an expensive product, a large amount of resources is used, which increases the environmental load. In the present study, this is referred to as the "correlation between the costs and environmental load".

This concept has been introduced in the "theory of misunderstanding of environmental issues", which has been widely supported in recent years: "many of the current ecological activities are nothing but a waste of money". However, it is very difficult to determine whether or not this is true. The price of a product reflects personnel expenses and profits, which are not resources in a precise sense. Of course, humans and companies can be regarded as a variable environmental load. However, whether or not this represents the "correlation between the costs and environmental load" is still an important environmental issue to be addressed.

However, motors and other components are required to produce a hybrid automobile, being different from those of a gasoline-fueled automobile, which is a cause of its high price. Therefore, basically, high prices are not attributed to personnel expenses and profits. The present study examined the usability of hybrid automobiles based on the "correlation between the costs and environmental load". Therefore, personnel expenses and profits are not the primary causes of this price increase. In the present study, the usability of hybrid automobiles was examined based on the theory of the "correlation between the costs and environmental load".

<Method for the validation: An examination of the usability of hybrid automobiles>

An examination was conducted to assess whether or not the introduction of hybrid automobiles is an effective environmental measure. For the examination, it is necessary to calculate how many years it takes for gasoline cost reduction due to a shift from a gasoline-fueled to hybrid automobile to exceed the difference in the prices of the two types of automobile. As explained in the preceding paragraph, it is an environmental load that should be considered. The present study adopted the theory of the "correlation between the costs and environmental load": the higher the costs, the greater the environmental load, or the assumption that, since the cost of producing a hybrid automobile is higher compared to that of a conventional automobile, a larger amount of resources is required to produce it, which increases the environmental load.

**Table 1.** Price and fuel efficiency of hybrid cars

| Maker | Model of a Car | Type | Price (Yen) | Fuel Efficiency (km/l) | Price Differences (Yen) |
|---|---|---|---|---|---|
| HONDA | Civic | 1.8G(AT_1.8) | 1974000 | 17 | 480000 |
| | Civic hybrid | MX(CVT_1.3) | 2454000 | 28.5 | |
| TOYOTA | Alphard G | AS(AT_2.4_Eight seater) | 3150000 | 9.7 | 693000 |
| | Alphard hybrid | Hybrid Eight seater_4WD (CVT_2.4) | 3843000 | 17.2 | |
| | Estima | G 4WD(CVT_2.4_Eight seater) | 3255000 | 11.4 | 1113000 |
| | Estima hybrid | G_4WD(CVT_2.4_Eight seater) | 4368000 | 20 | |
| | Crown Sedane | Super Deluxe (AT) | 2562000 | 11.4 | 519750 |
| | Crown Sedane | Super Deluxe(AT_2.0Mild Hybrid) | 3081750 | 13 | |
| | Harrier | 350G_4WD (AT_3.5) | 3444000 | 9.4 | 651000 |
| | Harrier hybrid | Harrier hybrid_4WD (CVT_3.3) | 4095000 | 17.8 | |
| | Kluger L | 3.0S_FOUR_Seven seater_4WD (AT_3.0) | 3318000 | 9.3 | 672000 |
| | Kluger hybrid | Hybrid Seven seater_4WD (CVT_3.3) | 3990000 | 17.8 | |
| | Lexus GS | 350 (AT_3.5) | 5380000 | 10 | 1450000 |
| | Lexus GS hybrid | 450h (CVT_3.5) | 6830000 | 14.2 | |
| SUZUKI | Twin | Gasoline A (MT_0.66) | 577500 | 21 | 777000 |
| | Twin hybrid | Hybrid A (AT_0.66) | 1354500 | 34 | |

**Table 2.** Division of annual driving distance

| | Annual driving distance (km/year) | User type |
|---|---|---|
| 1 | 3000 | Holiday user |
| 2 | 10000 | Mean annual driving distance of Japanese |
| 3 | 60000 | Taxi or long-haul truck drivers |

Tables 1 and 2 show all data used to conduct the examination. The subjects were eight types of automobile (Toyota-6, Honda-1, Suzuki-1)[12,13,14].

For each of these eight automobiles, both hybrid- and gasoline-fueled-types are available, and the former ones are more expensive. Differences in the prices of these automobiles and their fuel efficiency were examined. The calculations were based on the 10-15 fuel efficiency (the values that passed screening by the Ministry of Land, Infrastructure, Transport and Tourism)[15]. The gasoline cost was set at 155 yen per liter (mean cost as of October 10, 2013), and the annual driving distance was 3,000, 10,000, and 60,000 km. Whereas an average Japanese person drives 10,000 km annually, and mainly use their automobiles to go shopping at weekends drive 3,000 km annually. The mean annual driving distance covered by taxis and long-distance vehicles is 60,000 km[16]. The mean duration of ownership of an automobile by Japanese was set at ten years[17]. The examination was conducted using the following formula:

Formula 1: Annual cost of gasoline = gasoline fee × annual driving distance / fuel efficiency

Formula 2: Difference in the prices of two automobiles = the price of a hybrid automobile - that of a gasoline-fueled automobile

Formula 3: Annual gasoline cost reduction = annual gasoline fee for a hybrid automobile - annual gasoline fee for a gasoline-fueled automobile

The values obtained using these formulas were substituted into the following function, as shown in Figures 2, 3, and 4, to determine the number of years required for the reduction in the cost of gasoline to compensate for the price difference. The vertical orange-color dotted lines in Figures 2, 3, and 4 indicate the mean period of time using automobiles - ten years, which serves as the standard lines.

Function: Annual gasoline cost reduction × [x] - the difference in the prices of the automobiles (x: number of years)

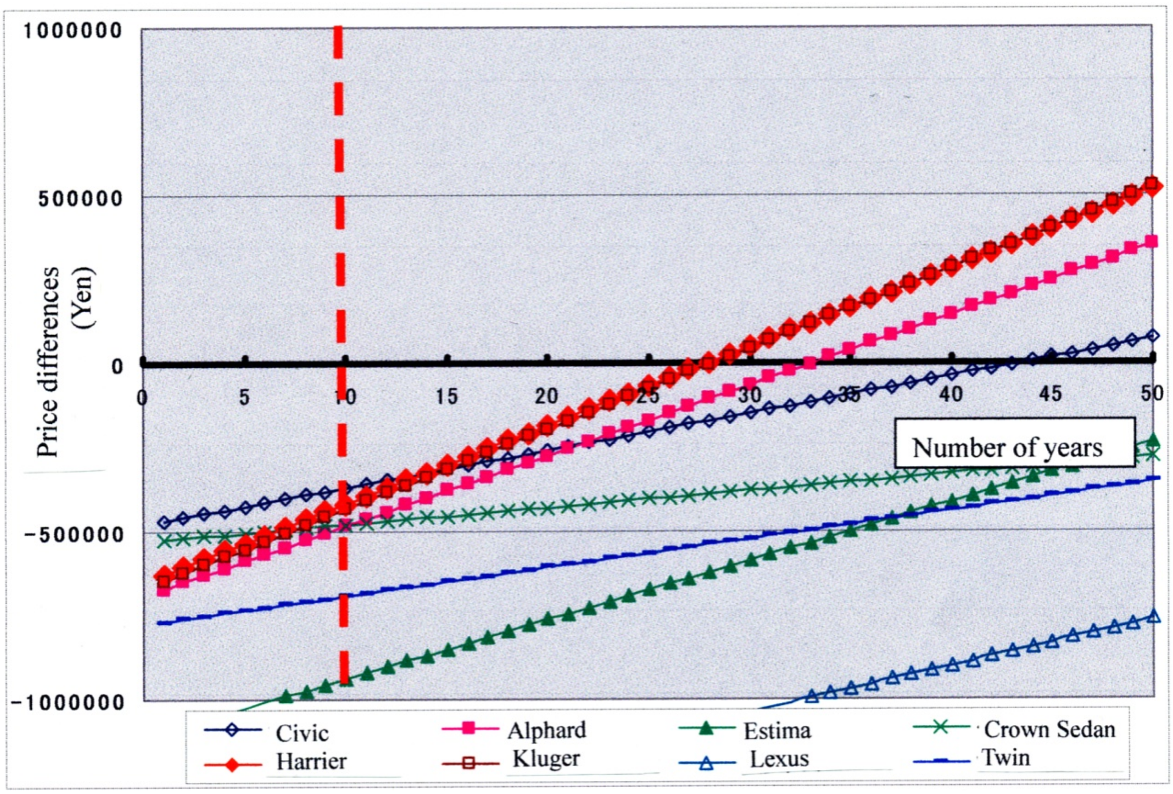


**Figure 2.** Number of years required for the reduction in the cost of gasoline to compensate for the difference in the prices of automobiles (when the annual driving distance is 3,000 km)

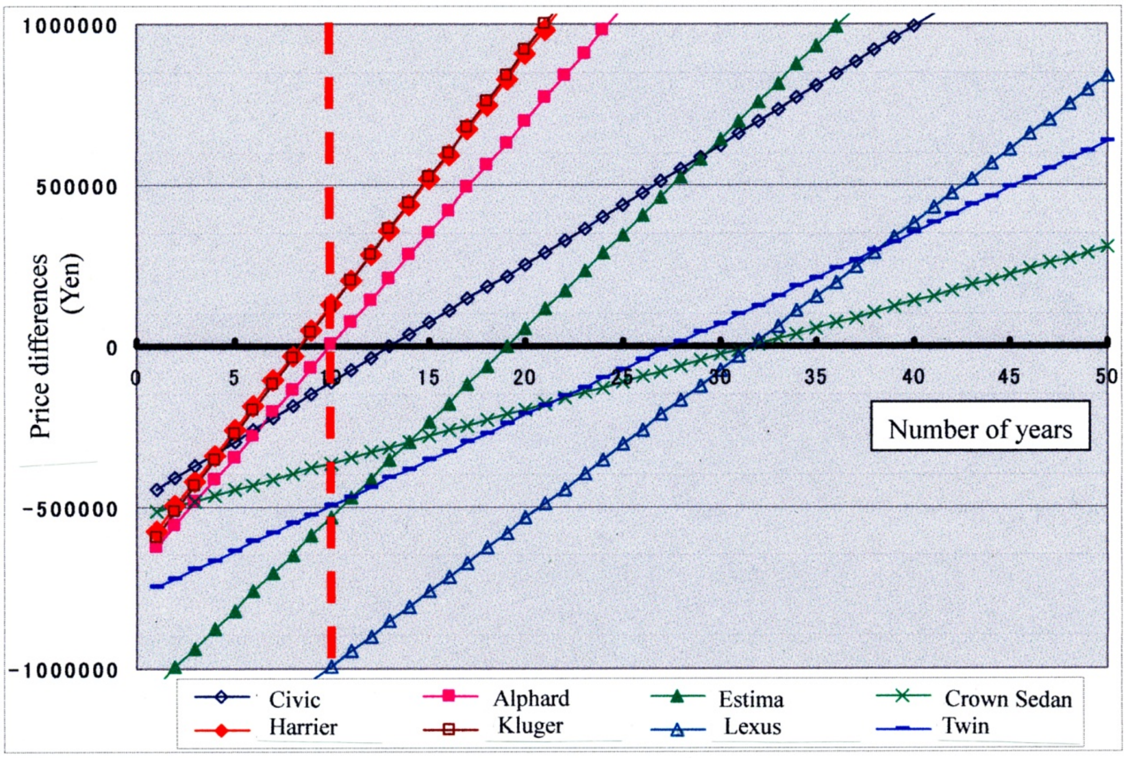


**Figure 3.** Number of years required for the reduction in the cost of gasoline to compensate for the difference in the prices of automobiles (when the annual driving distance is 10,000 km)

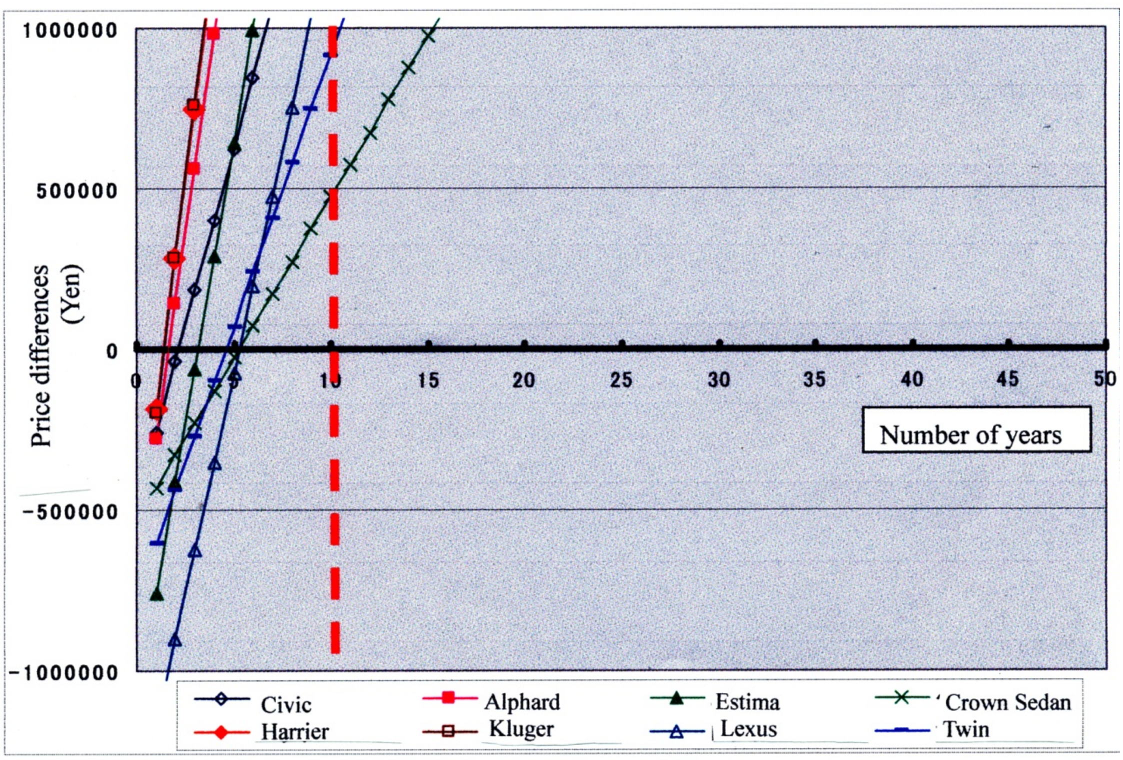


**Figure 4.** Number of years required for the reduction in the cost of gasoline to compensate for the difference in the prices of automobiles (when the annual driving distance is 60,000 km)

## 4. Discussion

Based on the validation results, the following four points were examined:

<Environmental measures involving hybrid automobiles from the viewpoint of the annual driving distance>

Tables 3, 4, and 5 show calculations of how many years it takes for the gasoline cost reduction to exceed the difference in the prices of the two types of automobile, based on Figures 2, 3, and 4. A comparison of these figures generated the following findings: If a person drives 3,000 km annually, the gasoline cost reduction as a result of shifting from a gasoline-fueled to hybrid automobile does not compensate for the price difference, over the period of car ownership, in the worst case scenario, which means that it is not an effective environmental measure. The results suggest that, when the annual driving distance is 60,000 km, the adoption of the hybrid system is an effective environmental measure. It was also suggested that, if the annual driving distance is 10,000 km - the distance covered by an average Japanese driver in one year, the measure may or may not be effective.

Currently, there are few long-distance trucks and other automobiles running 60,000 km per year that have incorporated the hybrid system. Therefore, the current use of hybrid automobiles in Japan is not effective.

<Correlation between the fuel efficiency and its differences>

Figures 5 and 6 show the relationships between the fuel efficiency, its differences, and factors influencing the economy of a hybrid automobile (economic balance between the reduction in the gasoline cost and difference in the prices of the two vehicles compensated for by the reduction). The relationship between the fuel efficiency and its differences is discussed first. The fuel efficiency was basically correlated with the differences. Considering that a difference in the fuel efficiency is an absolute value, this relationship is very interesting in that the fuel efficiency does not increase much when an automobile with a low fuel efficiency adopts a hybrid engine. This is attributed to the fact that the fuel efficiency of an automobile is closely associated with its weight. Hybrid engine technology incorporated into small and compact automobiles increases the fuel efficiency more because electric energy is conducted more slowly in heavier automobiles. In Japan, technology for hybrid engines has only recently been incorporated into small-sized and compact automobiles.

This is because advanced technologies are required to miniaturize hybrid engine-related products (or motors and other components). It is ironic that their compact size is an obstacle to the adoption of the hybrid system when small-sized automobiles benefit more from it.

<Discussion on the relationship between the fuel efficiency, its differences, and economic balance>

As explained in the preceding paragraphs, the fuel efficiency is correlated with the differences. This means that the higher the fuel efficiency of an automobile, the greater the increase in energy efficiency following the adoption of the hybrid system. The relationships between the economic balance and these two factors were then examined. As the relationship between the vertical bar and line graphs shows, no association was noted between the economic factor and fuel efficiency. In other words, there was no relation between an increase in the fuel efficiency and the cost of gasoline. It is commonly believed that the greater the increase in fuel efficiency due to hybrid technology, the greater the cost reduction of gasoline. However, despite this common assumption, the decrease in the cost of gasoline is attributed to other factors.

At present, the greatest advantage of hybrid automobiles is their “high fuel efficiency”. When viewed from standpoints of both the environmental load and economy, the essence of the issue cannot be understood by only focusing on “fuel efficiency”.

**Table 3.** Number of years required for the reduction in the cost of gasoline to compensate for the difference in the prices of automobiles (when the annual driving distance is 3,000 km)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Civic | 44 years | Alphard | 33 years | Estima | 64 years | Crown Sedan | 106 years |
| Harrier | 28 years | Kluger | 30 years | Lexus | 106 years | Twin | 92 years |

**Table 4.** Number of years required for the reduction in the cost of gasoline to compensate for the difference in the prices of automobiles (when the annual driving distance is 10,000 km)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Civic | 13 years | Alphard | 10 years | Estima | 20 years | Crown Sedan | 32 years |
| Harrier | 10 years | Kluger | 9 years | Lexus | 32 years | Twin | 28 years |

**Table 5.** Number of years required for the reduction in the cost of gasoline to compensate for the difference in the prices of automobiles (when the annual driving distance is 60,000 km)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Civic | 3 years | Alphard | 2 years | Estima | 4 years | Crown Sedan | 6 years |
| Harrier | 2 years | Kluger | 2 years | Lexus | 6 years | Twin | 5 years |

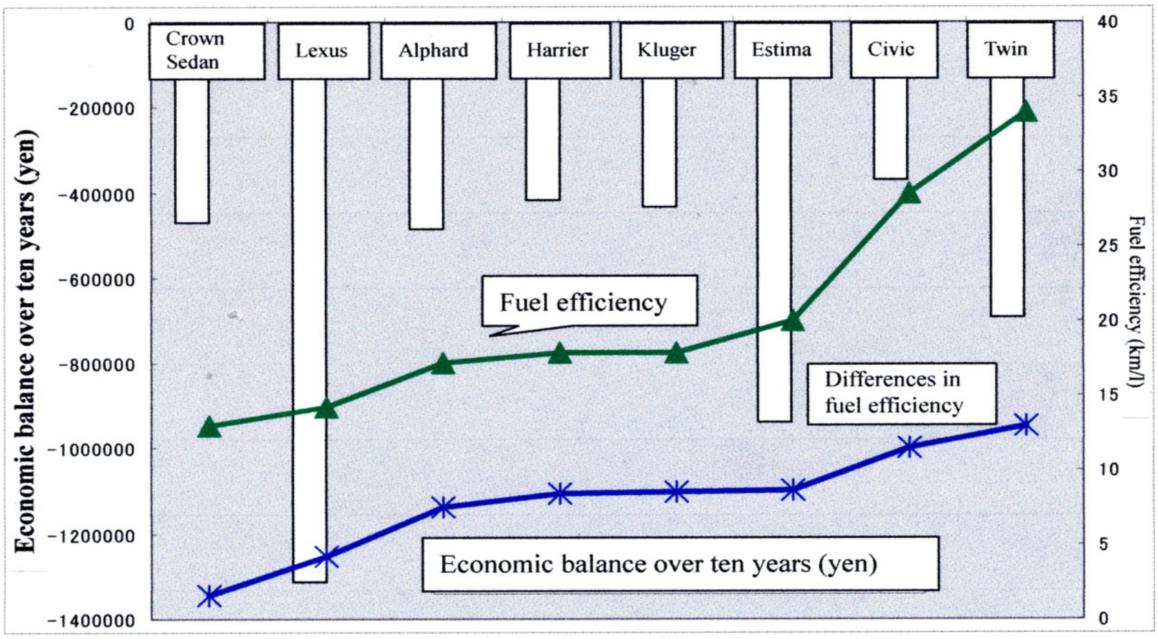


**Figure 5.** Relationship between price differences and gasoline consumption reduction over ten years (when the annual driving distance is 3,000 km)

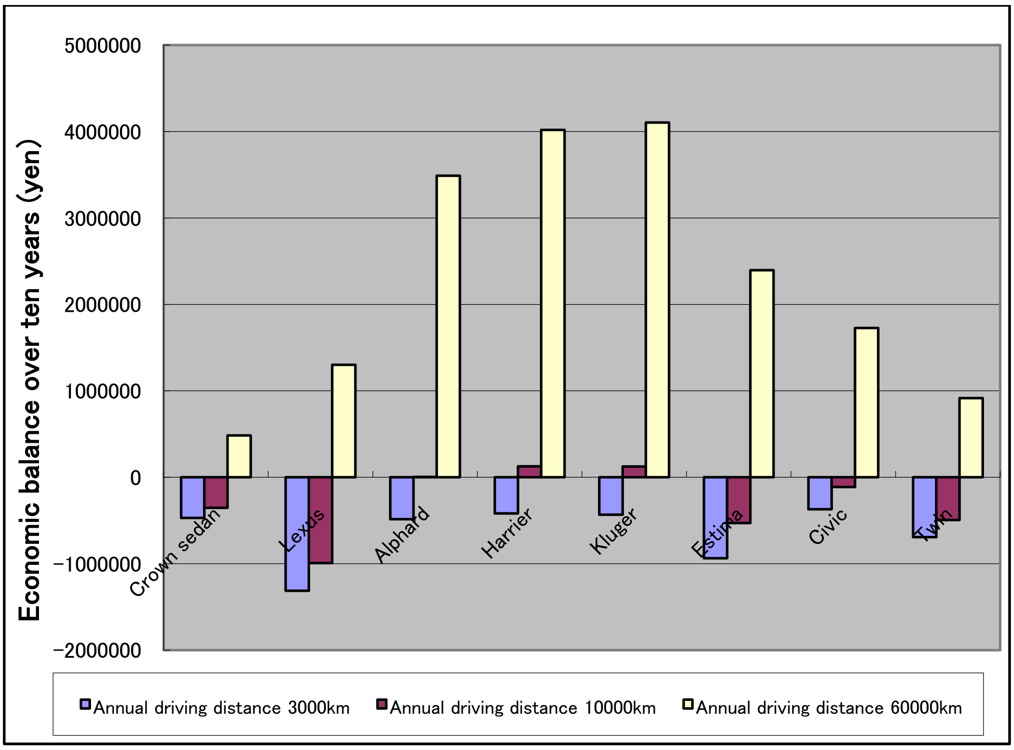


**Figure 6.** Economic balance over ten years (when the annual driving distance is 3,000, 10,000, and 60,000 km)

<Discussion on methods for the effective use of hybrid automobiles>

An examination was conducted to identify aspects of an automobile contributing to reducing the cost of gasoline other than fuel efficiency, focusing on Formula 1, used for the validation in the preceding paragraph.

Formula 1: Annual cost of gasoline = gasoline fee × annual driving distance / fuel efficiency

In this formula, the cost of gasoline and annual driving distance were set at 155 yen per liter and 10,000 km/year, respectively. Using the formula, differences in gasoline consumption between gasoline-fueled and hybrid automobiles can be calculated. First, gasoline consumption that can be reduced by shifting a gasoline-fueled automobile that runs at a fuel efficiency of 5 km/L to a hybrid automobile and increasing the fuel efficiency by 1 km/L was calculated. Then, decreases in gasoline consumption when gasoline-fueled automobiles running at a fuel efficiency of 10 and 15 km/L adopt hybrid engines were also calculated, as shown in Figure 7.

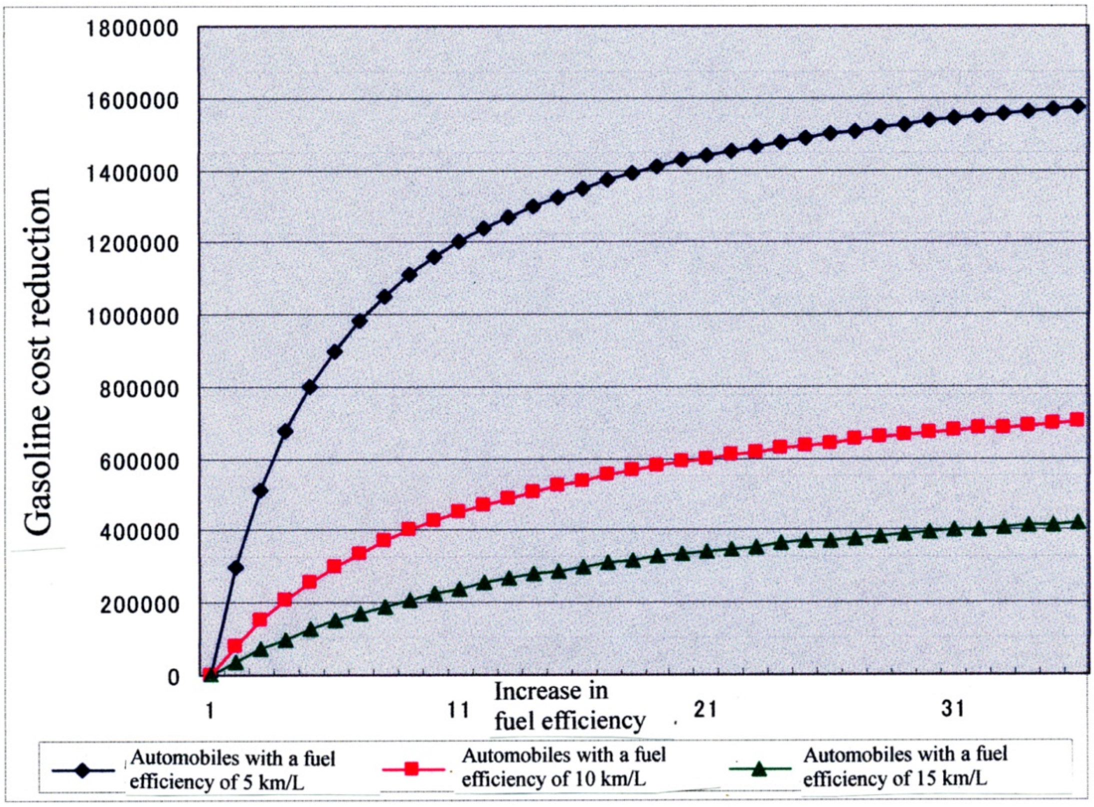


**Figure 7.** Changes in gasoline cost reduction affected by differences in fuel efficiency

**Table 6.** Examples of the inverse relationship between gasoline consumption and fuel efficiency

| | Gasoline-fueled automobiles | Hybrid automobiles | Gasoline consumption reduction | Difference in fuel efficiency |
|---|---|---|---|---|
| Changes in fuel efficiency (1) | 1km/L⇒100L | 5km/L⇒20L | 80L | 4km/L |
| Changes in fuel efficiency (2) | 20km/L⇒5L | 50km/L⇒2L | 3L | 30km/L |

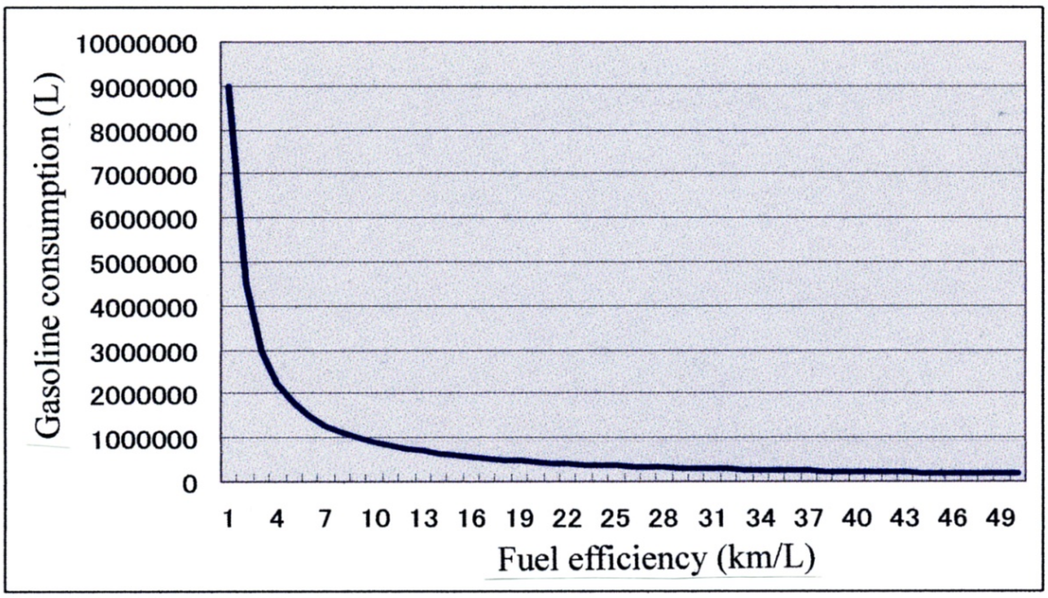


**Figure 8.** Relationship between the cost of gasoline and fuel efficiency (when the cost of gasoline is 155 yen per liter and annual driving distance is 10,000 km/year)

Figure 7 indicates that, when the rate of increase in fuel efficiency is the same, the adoption of the hybrid system in gasoline-fueled automobiles with a low energy efficiency reduces gasoline consumption. Furthermore, the results suggest that gasoline consumption can be further reduced by implementing an improvement in fuel efficiency from 5 to 9 km/L rather than tripling the number of automobiles with a fuel efficiency of 15 km/L. Examples shown in Table 6 explain this. When automobiles run at a speed of 100 km, an energy efficiency improvement from 1 to 5 km/L by adopting the hybrid system in gasoline-fueled automobiles, as shown in (1), reduces gasoline consumption by 80L. However, an energy efficiency improvement from 20 to 50 km/L only reduces gasoline consumption from 5 to 2 L. As Formula 1 in Figure 9 shows, the fuel efficiency is inversely proportional to the cost of gasoline. Therefore, a more effective environmental measure can be implemented by moderately improving the fuel efficiency of automobiles with a low energy efficiency rather than increasing that of fuel-efficient ones.

The following is a summary of the preceding discussions: Firstly, people who drive a longer distance annually tend to prefer hybrid automobiles. If you want to purchase an automobile for personal use such as shopping, you should select a compact, fuel-efficient automobile, which has few adverse effects on the environment. Secondly, hybrid technology is the most effective when used in automobiles with a low fuel efficiency. Since the fuel efficiency of light and compact automobiles is high as they are, the adoption of hybrid technology in them is expected to make little difference in terms of environmental improvement, although their fuel efficiency will be “slightly increased”. Considering these two points, the introduction of hybrid technology to large-sized automobiles is the most effective as an environmental measure. The adoption of hybrid technology in large-sized automobiles is particularly effective because they are usually used in work settings and mean distances they are driven annually are marked.

## 5. Conclusions

In recent years, there has been increasing recognition of hybrid automobiles among consumers and in many countries as a promising environmental measure. In 1997, the TOYOTA PRIUS entered the market, and, in 2008, a plug-in hybrid automobile (hybrid car that can be charged from a standard home outlet) was introduced for the first time at the North American International Auto Show held in Detroit, U.S.A., which attracted public attention[18]. In the automobile manufacturing industry, improvements in fuel efficiency and environmental efforts are becoming increasingly important for manufacturers to survive. A variety of light and compact automobiles have adopted hybrid engines in recent years. The fuel efficiency of compact automobiles is basically high. Taking advantage of this feature, manufacturers place compact automobiles that have incorporated the hybrid technology on the market under the catchphrase of “Experience the automobile with the highest fuel efficiency in Japan”. Currently, automobile manufacturers are involved in the development of small-sized motors to further increase the fuel efficiency of compact automobiles. However, companies are required to change their “direction and viewpoint” and improve the low fuel efficiency of large automobiles. The best use of hybrid technology as an environmental measure is to incorporate it into automobiles with a low fuel efficiency so that both hybrid- and non-hybrid-based automobiles with a high fuel efficiency are available.

Companies involved in long-distance transportation are also advised to adopt hybrid engines for their taxi vehicles and trucks, although there are problems to be addressed, including emissions from diesel automobiles and a significant disadvantage of the hybrid system while driving on highways. Moreover, the government should increase its efforts to improve the fuel efficiency of large-sized vehicles, including trucks, as a national policy.

To improve the fuel efficiency of large-sized and other less fuel-efficient vehicles, it is necessary to raise public awareness of energy efficiency and recognize companies that have implemented energy-saving measures and support their economic development. These points must be considered when developing environmental measures in society. Hybrid engines have also been adopted in increasing numbers of large-sized automobiles in the U.S.A. and other countries [19]. As a country with top-level hybrid technology, Japan should lead other countries in terms of not only its technology but also its applications.

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