Quantitative Research on Diffusion Speed and Price Transition of the Car Market for Future Prediction of Electric Vehicles

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Abstract

Predicting how the electric vehicle market will develop from now on is a very important issue for not only countries that have led the car market such as Japan but also for countries that are going to develop. Then, in order to predict the diffusion of electric vehicles, the diffusion speed and price transition of former cars was analyzed quantitatively, and research which clarifies the prediction method of the diffusion rate of a car was performed. The universal relation about the sale and diffusion of cars became clear by considering a technical element in it. Conventionally, the demand forecast of a new product was carried out after the sale start. Past experience and a specialist's opinion were adopted in part. In a prior study, it was shown clearly that there was great influence by the leading role of engineering development and production and sale of a key device in each product. The relationship means whether the process of technology development and production sales is initiated by the device manufacturer only or through collaboration with the product manufacturer. In this paper, the results could be extended to the auto industry and so the same tendency was observed. Furthermore, the results were applied to predicting diffusion and the price of an electric vehicle, and if the problems, which were the interference of the present diffusion, can be solved, the earliness of diffusion and transition of the price of an electric vehicle could be decided by the development speed of the battery. The problems were both the short mileage from one charge and the more expensive price in comparison a common vehicle. According to the result of consumer electronics apparatus, the case was that 20 % of diffusion will be carried out in about 5 years after sales start, and the prices at that time are 50 % or less compared with a start price.

Keywords

electric vehicle, consumer electronics product, consumers' durables, diffusion rate, global competitiveness

1. INTRODUCTION

1.1 Purpose of this research

It has been shown clearly that the transition of price and the diffusion of consumer electronics products have a close relation with the characters of key devices by carrying out quantitative analysis [Yamaguchi, 2009]. The relation was determined by the engineering development process and the structure of production and sales of the key devices. Then, passenger cars were analyzed concerning whether these relations would have universality based on past sales data in Japan. It is the purpose of this paper to apply results to the prediction of the diffusion rate of future electric vehicles.

There were various types of conventional demand forecast and the prediction method of price fluctuation, such as methods using an advanced mathematical model or using the opinion of a specialist and consumers. However, since the behavior of a new product was modeled on a certain expected motion, it must tend to become an extension of the conventional prediction. Therefore, when new products began to spread faster than ever before and together with a drop in the price, the corporate management might suffer damage depending on this prediction. It has been shown that the diffusion prediction of consumer electronics products is done by numerical quantification of products. This research aims to contribute to the management of car makers, governments and users by predicting the diffusion of electric vehicles in the future by a quantitative technique on this problem.

In addition, this research clarified a process of diffusion; however, it does not describe the methodology or the strategy of competition in the business which was accepted in a market.

1.2 Importance of a technological approach

Recently, analog products of consumer electronics products have been major. The diffusion of new products required a comparatively long period. Even when sales fell behind other companies at the time of commercialization, if the product is of superior quality and lower price compared with other companies, they might be able to catch up. However, it has been very difficult to catch up once digital products are behind

such as the present flat TV. The reason was "for the speed of diffusion to be twice as quick as the former, and for a price to fall 30 % each year." In order to stand on a predominant position, it is necessary to be not only ahead with engineering development, but also to precede in all phases of corporate activities, such as production capacity preparation, sales channel maintenance, equipment expansion, activation of a business organization, and employees' enhancement in skill. This is very important at the start of the electric vehicle business.

Even if prediction is possible, of course, it is not enough to win the competition in business. Corporate activity is called "practical use of a person, a thing, and money." A result is obtained by making organic combination of management resources best. Therefore, it cannot be overemphasized that concrete activity is the most important. Books on economics, management documents, and institutional research do not deny this importance in meaning either.

1.3 Method of approach

The method of approach which had been developed focused on the period until a diffusion rate would be 20 % from the sale start [Yamaguchi, 2009]. The diffusion of products and transition of price in this period were analyzed, the engineering development of the key device and the state of production and sales were analyzed further, and the relation between both results period were investigated. The meaning of 20 % of a diffusion rate means that a maker's mass-production organization was fixed and the prices of products became stable according to the effect. For example, in Japan, a 20-inch color television was put on the market at 300,000 yen in 1960 and a penetration rate for households exceeded 20 % in 1970, the price was 150,000 yen. The ranking of the maker's market share was mostly decided at this period. Detailed data of consumer electronics products before 20 % were difficult to obtain, and after 20 %, new competitive conditions such as sales network or an intentional price strategy increased. So, there was inconvenience in the conditions of diffusion of early estimating and it was removed from analysis.

1.4 Investigation of preceding research

There is much written about the history of car development [Okazaki et al., 2002; Eckermann, 1996]. The trends from the early stages of the auto industry and also the earliness of spread and price transition were described. However, the prediction method was not described. Moreover, there has been much research which analyzed development of the auto industry of Japan in 1990 and afterwards from the viewpoint of "competitive power" [Shimokawa, 2006; Nomura Research Institute, 2007; Fujimoto, 2007]. The possibility that the manufacture power of the auto industry would improve skills, and this would have gained global competitiveness, was studied. The fall of global competitiveness of Japan's manufacturing industry was also described, and many points for improvement were suggested. However, when new products were put on to the market, neither the necessity of foreseeing "the earliness of diffusion", "transition of a price" before it, nor a method of prediction were described.

Concerning an electric vehicle or a lithium ion battery, they are still under development now, and there are also reports for the possibility of future evolution and proposals [The Study Group about the Next-generation Battery Technology, 2006]. This is a report of the research of a car or battery technology, and, naturally estimates based on present technology, so this reports showed a target number of diffusion or price only. It is not considered to clarify diffusion and price universally from the comparison of other industrial fields.

There has been research in which car development of each country and the role of the components industry were described. [Kobayashi, 2005] This research summarized developments of the auto industry in each country as progress from the past from a viewpoint of components. This research is very significant in examining a future trend. However, it did not touch on the case of big technology change. The unique feature of this research will perceive the key device which has achieved an important role in products. Furthermore, it will relate diffusion and the prices of new products with the technical contents of the key device.

1.5 The results of past investigation

This section describes the past results of research of the diffusion of consumer electronics apparatus which are already clarified. In past reports, the transition of a period until a diffusion rate would be 20 % from the sale start of new consumer electronics apparatus (it abbreviates to a 20 % diffusion period after) and a price was analyzed. The 20 % diffusion period which shows the earliness of diffusion was divided into 4-5 years, and 7-9 years, the real price ratio was divided to over 50 % or less than 50 %, and products were classified. Because certain products diffused over a long time period, the price ratio normalized with the rise of per capita GDP into a calculation named the real price ratio. The data of Angus Maddison was utilized concerning the compensation of per capita GDP [Maddison, 2009]. The calculation formula is shown below.

The real price ratio = (X/Y) × 100 (%), X = 20 % of a price / a price at sale start, Y = GDP per person at the time 20 % / GDP per persons at sale start.

As a result, each product was able to be distributed into blocks A to D.

A: a black and white TV, a liquid crystal television, a DVD recorder (20 % diffusion period is 4-5 years and a real price ratio is 50 % or less)

B: a cathode-ray tube type color television, an IC color television, a VHS tape recorder, a VHS-C video camera, a DVD player (20 % diffusion period is 7-9 years and a real price ratio is 50 % or less)

C: a portable music player (20 % diffusion period is 4-5 years and a real price ratio is over 50 %)

D: a digital camera (20 % diffusion period is 7-9 years and a real price ratio is not over 50 %)

The important aspect of this result was that the products for 4-5 years and 7-9 years could be classified into only two categories and there were no items between them.

In order to examine why diffusion speed and the difference of price decline happened, the behavior of each key device with a diffusion rate that would be 20 % from a sale start was investigated. For the spread of new products, important elements are generally performance and price. Key devices determine these important elements and they are paid attention. Evaluation was carried out by classifying a key device according to the following items: who performs the technical development of the key device, whether the production and sales is in-house by the device manufacturer only or the production manufacturer, and whether both make a strong relationship and develop a monopolistic position. As a result, the products were divided into groups of completely the same classification as the classification described above. The result is shown below. The name of categories used was the same.

A: The products in which the key device has the leadership of engineering development and production and sales.

B: Development of a key device is performed by cooperation from the product manufacture side. This is because know-how is stored on the product manufacture side. The key device side performs production and sales independently, or the product manufacture side produces them in-house.

C and D: Products which the product manufacturer and device fabrication side cooperated strongly in respect of the production and sales of the key device, and built a monopolistic position in the market.

As a result of the above analysis, it became clear that the earliness of the diffusion of products and transition of price are related with the character of a key device. So, Table 1 was obtained by the comparison of key device engineering and production to products diffusion and price. When a key device was analyzed regarding the technology and production and sales and then applied to Table 1, after blocks A to D were decided, the future figure of the product could be drawn.

Table 1 is a result of the limited samples. However, it can be concluded that these results could be applied to other consumer electronics products for the following reasons. When the key device side developed independently, the diffusion of products was the earliest. On the other hand, when the product side took a part in device development, diffusion took more time comparatively. In the latter case, the reason was the long time needed for the quality assessment and improvement work with the device side and the product side together. Sometimes device improvement was repeated again according to the demands of the side of apparatus development. Furthermore, when the key device and products side carried out mutually-independent dealings, the prices of products were lowered and diffusion progressed naturally. When a close relation was

Table 1 Classification table of feature and diffusion rate of key device in products

		Engineering development		
		Independent	Cooperation	
Production and sales	Independence or in -house production	**A**	**B**	At diffusion rate 20 %, price falls 50 % or less
	Close cooperation	**C**	**D**	The price maintains, improvement in functional.
		decided by device development speed (5years)	decided by products development speed and growth of GDP (9 years)	
		Earliness of the diffusion		

Price decline of products

made, a monopolistic relation was built in comparison and the price was fixed. The reason was that those makers disliked price competition and went into function competition. In the open relation, a lower price was achieved and advanced diffusion.

2. PREDICTION OF THE EARLINESS OF SPREAD AND PRICE TRANSITION OF ELECTRIC VEHICLE

2.1 Meaning of research

In recent years, electric vehicles have come to attract attention because of the lack of oil or from a viewpoint of environmental protection. Now, the hybrid car takes the spotlight of electric vehicles, and, although the price is comparatively high compared with a gasoline-powered car, the sales are good in Japan. However, in the past, the shift towered to an electric vehicle failed due to the high price against performance [Carson and Vaitheeswaran, 2008]. As a result, there were some people who had a skeptical opinion of diffusion among the makers who manufacture electric vehicles, the companies which promote use and diffusion, organizations, the government, and also consumers. The greatest reason was the existence of the problems of capacity and the price of a battery. This paper will consider "transition of price" and "the earliness of diffusion" of electric vehicles using the results from the preceding chapter taking notice of the lithium ion battery.

2.2 Extension to auto industry of the prediction technique of the earliness of spread and price transition

The possibility of extending the prediction technique described previously to a passenger car is examined. In the diffusion rate analysis developed by the author, the character of a key device is an important element which determines the relation between diffusion and price. Then, compared with other consumer electronics products, the kind of category for a passenger car is examined. Although examination requires two or more samples, as a product, the passenger car is a single category. Therefore, the progress of auto- industries of two or more countries in the world was taken as a sample. The earliness of spread and price transition of the passenger car of each country which has developed uniquely was analyzed. The result is shown in Table 2. The following countries were picked up as samples: the United States, which has promoted the passenger car in the world, Germany, which developed the car in the early stages, Japan, which achieved high growth after the war and took its auto industry to the world, and South Korea, which, although coming late into the auto industry, captured the market share quickly. In the case of Japan, the time of 20 % of the diffusion rate was found from the data of "the penetration rate for households of the consumer behavior forecasting survey of Cabinet Office" [Cabinet Office, 2009]. Germany and South Korea were presumed from the transition data of the number of passenger car possession [Daily Automotive News, 2008]. There was no clear data about the United States.

First, the character of the engine, which is a key device, was analyzed. The status of development of the power system module of the engine and power transfer, fueling, and an exhauster style at 20 % diffusion period was analyzed. As an example, Japan will explain this status. In Japan, the full-scale Japanese passenger car was put on the market in 1955, and the diffusion rate reached 20 % in 1970. A diffusion rate is the rate of the number of cars to the number of families. A 1500-cc small passenger car was first

Table 2 Diffusion and price of car of each country, and per capita GDP

	Sale start	That time price	GDP per person at that time ($)	Time of 20 % of a diffusion rate	That time price	GDP per person at that time ($)	A period until 20 % (year)	The price ratio normalized by GDP (%)
Germany	1950 Volkswagen	3790 marks [USD 1994]	3881	1965	USD 2000	9186	15	41
Japan	1955 Toyopet	JPY 1,020,000	2771	1970	JPY 1,400,000	9714	15	39
South Korea	1974 Pony	USD 6000	3015	1986	USD 7000	6263	12	56
The average of Germany, Japan, and South Korea							14	48
United States	1938 American car	USD 2200	6126	1960 or before	USD 2000	11328	22 or less	49 or less
	1908 Ford T type	USD 850 (touring type)	4561	unknown	unknown			

The U.S. Department of Commerce announced that 54 % of all the U.S. households held a passenger car around 1936. But the time of 20 % is unknown.
Per capita GDP from an Angus Maddison homepage, it is http://www.ggdc.net/maddison/.
The Ford T type was sold for 290 dollars in 1924.The GDP per person at that time was 6233 dollars.

developed by a Japanese maker, and it was the start of automobile diffusion by a domestic car. While consumers' interest increased, the demand for a more highly efficient car increased. Existence of the Japanese Grand Prix race etc. which was held in 1963 also serves as the backdrop. Therefore, development of a higher-output engine was recommended and the new mechanism of DOHC was introduced. In 1970, it was decided that regulations on exhaust gas would be carried out in the United States (Muskie Act) and also Japan. The CVCC engine of Honda was being developed at this time. Furthermore, an exhaust gas purifying facility by a three-way catalyst was introduced. In order to cause the reaction of a catalyst efficiently, the ratio of the air and fuel which are sent into an engine had to be controlled correctly. Therefore, an expensive electronic-controlled type fuel injector was developed and introduced. Improvements which chiefly make an engine highly efficient were added during this time. As explained above, the automaker naturally improved an engine and a power system naturally by themselves, and production was in-house again. In the company, the engine development section and the body development section undertake and promote close cooperation with each other. The above measure is detailed in the literature which studies the history of the car [Okazaki, 2002]. The above data was researched through the specifics of past typical cars on the internet [Meisyakan, 2009].

The maximum output of an engine was normalized by cylinder capacity, and the transition of the period is shown by Figure 1. In a comparison of around 1955 to 1970, the maximum output per volume of cylinder capacity increased by about double. This tendency was almost the same for the cars of each cylinder capacity. In the history of the passenger car as shown above, it is thought that there was desperation to catch up to

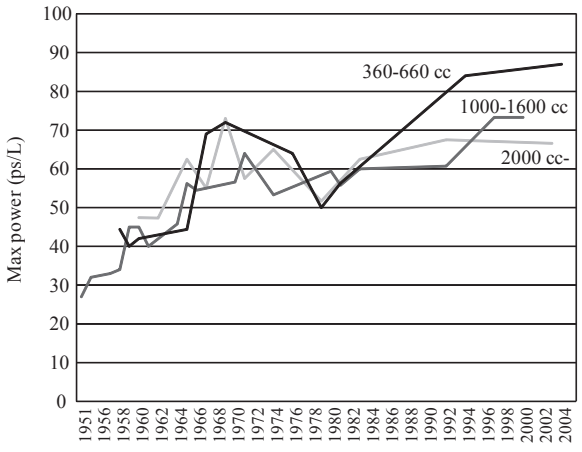

Fig. 1 Maximum output per volume of cylinder capacity of engine of Japanese passenger cars

Table 3 Change of body weight of typical type of passenger car in Japan

	Around 1955	Around 1960	Around 1970
Regular size subcompact car in Japan	1,210 kg	1,265 kg	1,300 kg
Small size subcompact car in Japan	960 kg	940 kg	945 kg

Source: From Toyota Motor Corporation catalogue

the performance equivalent of overseas passenger cars during this period. By around 1970, a maximum output came to show a steady value, and because that value became almost equivalent to the value of the passenger car in Europe, it can be said that it had finally caught up. Furthermore, the transition of body weight, as shown in Table 3, was given the same method of examination. Since body weight changes considerably according to the maker's design philosophy and body or interior design, and also in order to eliminate this influence as much as possible, a famous type of Japanese car was investigated. With the increase of maximum output, it can be thought that this would lead to an increase in weight in order to achieve improvement in performance of the power system and running system. As for the result, compared with 1955, 1970 showed almost no change in body weight, so weight saving of the body had progressed. Body weight contributes greatly to the fuel consumption performance of a passenger car. The development and production of the engine, as a key device of a passenger car, was due to in-house and close cooperation between the engine shop and body section. The feature of the engine, which is a key device, is applied to the prediction technique in consumer electronics products based on the above argument, and in regard to which category a car belongs to, a result corresponds to B of Table 1.

Next to be discussed is the earliness of diffusion and the fall of price. Table 2 shows the following: (1) in the period of spread to 20 %, the average years of Germany, Japan, and South Korea were 14 years which is a long time compared to other consumer electronic products, (2) also when a diffusion rate became 20 %, the actual price showed almost no change or was rising. However, the real price ratio normalized by per capita GDP was 50 % average, (3) three nations of GDP per person of sale start time were 3,000-4,000 dollars. Regarding the United States, the time of 20 % diffusion rate was not clear, so it was removed from this analysis. It is shown in the lower column as a reference. When the diffusion rate became 20 %, a real price ratio fell to 50 % or less at the time of sale start,

and it also meant a passenger car can be set to the position of B of Table 1 too. However, since the period of diffusion was 14 years, it differs from the period of consumer electronic products. According to the results of Table 2, the price of Japanese cars increased from 1955 to 1970 by 40 %. The number of passenger cars in both Germany and South Korea increased by less than 15 %. However, it is thought that efforts were mainly concentrated on improving efficiency by focusing on the power system during this period, and as stated above, cost pressures were strong. On the other hand, for this reason, cuts in the cost of materials, rationalization of productivity, etc. were performed. Efforts were made in the form of a model change. The Toyopet Crown, in Table 2, has carried out model changes since the sale start for every four to five years. The period of model change is time to carry out car engineering which reaches the performance that consumer's request, and it is also a period required for realizing a cost cut. It can be understood that the price is maintained or raised as a result. On the other hand, if the per capita GDP went up every year, then the real price would go down. When the price becomes equal to the price which consumers requested, it is thought that the diffusion reached 20 %. It can be said that the real price ratio was required to be about 50 % in order to carry out 20 % of the diffusion rate, if this case of the three nations is considered, the period for achieving 20 % was about 14 years. 14 years of development speed and the growth of per capita GDP will determine the outcome and finally correspond to B of Table 1.

According to these results, it can be concluded that an evaluation method of consumer electronics products can be used when the character of the engine, which is a key device in the car, is observed.

2.3 Character of the key device of an electric vehicle and prediction of diffusion

In this paper, it was shown clearly in the analysis of 2.2 and Table 1 that engineering development of a key device, composition of production, and sales as a factor determine the speed of the diffusion of cars. Based on this result, the earliness of spread and price transition of an electric vehicle replaced with a common vehicle is predicted. Many makers in the present world are developing electric vehicles, and preparations for production are being made. Firstly, a key device is specified. Since electric vehicles are in a developmental stage, a detailed cost structure is not clear. Although it is indirect, estimation can be made from the data of the cost structure of a hybrid car. The result is shown in Table 4. Concerning the cost structure of a common vehicle and a hybrid car, the Cabinet Office synthesis

Table 4 Presumption of price of electric vehicles (equivalent to a car of 1.5 L)

	Common vehicle (1000 yen/set)	Hybrid car (1000 yen/set)	Electric vehicle (1000 yen/set)
Engine	432	432	0
Chassis	198	198	198
Body	414	414	414
Electronic auto parts and electronic parts	360	360	360
Article	396	396	396
Vehicle common parts (subtotal)	1,800	1,800	1,368
Power control unit		80	80
Others		80	80
Battery		160	3200
Hybrid or EV peculiar parts (subtotal)		400	3440
The estimated total cost	1,800	2200	4808

Source: Cabinet Office synthesis Institute for Economic and Social Research.
The author corrected for an electric vehicle (the battery price set up by 20 times the hybrid.).
The indirect cost is contained in the price of each part.

Institute for Economic and Social Research commission investigation was quoted [Cabinet Office, 2006]. It is possible to develop an electric vehicle if the cost is simplified, the engine is removed from hybrid vehicles, and the battery size is bigger. The result is written in the right column of Table 4. According to the results, at 70%, the battery is a major part of the electric vehicle cost which includes a motor and power control. It can be said that the battery is a key device if the fact that a power generating part determines basic performance as a car is taken into consideration.

Many batteries for electric vehicles are developed within the organization of cooperation between a battery maker and an automaker. In regard to production and sales, the automaker and the battery maker have taken the organization of close cooperation [Cabinet Office, 2006]. Concerning the battery as a key device, the above condition is applied to Table 1 and the diffusion of electric vehicles and transition of a price are assumed. As a result, an electric vehicle can be recognized to belong to category D in Table 1. The speed of the diffusion of products that belong to category D will be decided by the development speed of a car (apparatus development side) and by the growth of GDP per person. Furthermore, the real price of the electric vehicle that belongs to category D will be maintained with function improvement instead of fall down. However, since the following problems exist, this prediction is inapplicable. The sales target of the electric vehicle, which the automaker is presently developing, is a replacement market of the popular common vehicle. In order to sell in the market, you have to overcome the problem of shortage of mileage by one charge and also the problem of a high price. With a full tank of fuel, a 400-500-km continuous run is possible for a common vehicle, and it can be filled up easily at oil stations currently set up all over the country. In the proposed electric vehicle, 160 km is the limit and a boosting charge station has not been introduced yet. According to Table 4, the price a battery is high and the price of an electric vehicle is as high as 2.6 times compared with a common vehicle. Therefore, except for special uses, there is no chance to make electric vehicles popular in the world. Table 1 is clarified about a process in which a product is received in a market and spreads, and since this does not describe the methodology and strategy for being accepted in a market, it cannot be assumed through the use of Table 1.

If the problem of mileage and the problem of a price are solved, the kind of diffusion that is carried out can be presumed. If sale is started and leads to a start of diffusion, the battery maker will make an effort to achieve more capacity and price reduction by engineering development. Since the battery maker can carry out technical development contents through self-management, independent development is carried out by the key device side. If diffusion starts completely, sales will start independently of each battery maker, and it will be sold to the electric vehicle makers in the world. Each automaker carries it in their electric vehicles, and will sell it all over the world. This condition belongs to category A, just as a liquid crystal television in Table 1. According to Table 1, the diffusion speed is decided by the development speed of the key device side.

In this case, the main development subject of this battery is price reduction. For this, improvement in the mass-production technology of a battery is necessary. Although structure is simple, the lithium ion battery has issues depending on equipment, such as guarantee of safety, the stability of mass production, and improvement in the yield of material. The development speed of a key device is decided with the speed of evolution of equipment. This is a situation just like the equipment development competition that competed for glass size with the liquid crystal panel [Nakata, 2007]. If the speed of evolution of lithium ion battery production equipment is the same as the speed of evolution of equipment for a liquid crystal panel, 20 % of rapid diffusion will be carried out in five years. Just as an electric vehicle solves the present problems and steps forward toward diffusion, it may follow the same progress as digital consumer products.

2.4 Capacity of battery and problem of price

The growth of energy density increased the performance of the lithium ion battery which is a key device. [Maruyama, 2009] Further progress will be made from now on and a theoretical limit is also considered that the speed of improved efficiency will be saturated for a certain reason. Regarding reduction of price, material cost and material processing cost need to be decreased [Nelson et al., 2009]. High-priced cobalt is used as a raw material. The manufacturing process of the battery has not reached the level of mass-production. For these reasons, a method of supporting price reduction has not been found. There are only two ways of solving this problem. The first is the method of expecting and solving new engineering development. At this time, this method is not possible. The second is discovering an application which solves this problem. Since electric vehicles are future products, they have various possibilities in the future. Although the electric vehicle replaces the present common vehicle, in addition, the products which should be observed are electric motorcycles. In China, the electric motorcycle and small electric vehicle adaptations

are put into practical use. The electric motorcycle in China solved the problem of mileage and the problem of the charge station, in order for charge to be possible in a home or an office. The problem of the price was solved by the adoption of a lead battery, without using an expensive lithium ion battery. As a result, in the Shanghai area, electric motorcycles began sales in 2001, and sales were recorded at 21 million in 2008, and rapid diffusion was seen [Shioji, 2009]. Although the number of diffusion rate is not clear, in the Shanghai area, it is expected to be over 20 % so far. There is a high possibility that there will be changes to lithium ion batteries from now on, and diffusion will progress rapidly. The small electric vehicle will be sold as an application. Since this is designed very simply compared with the common vehicle, the price is also low. If Chinese consumers accept performance and price and if the traffic regulations approve this vehicle, it may spread quickly. This case is category A of Table 1. Supposing the production quantity of a lithium ion battery increases by the popularization of new forms of electric vehicles, such as a small electric vehicle, the price decline of the whole lithium ion battery may progress by the volume efficiency. There is a high possibility that the effect will attain to a common electric vehicle. Although this was also quoted for the example of a liquid crystal television, in the early stages, the price of large-sized liquid crystal panels was high, and sales were hesitating. Medium-size liquid crystal panels were produced in large quantities for notebook PCs at the time. As a result, the price of large-sized panels fell. The outlook appeared in the price of large-sized liquid crystal panels by this effect, and sales of large-sized liquid crystal televisions began. Manufacture was difficult for the big screen liquid crystal panel at that time. Therefore, a 37 inch type flat TV cost 800,000 yen. Nobody expected that the price would later fall to about 1/10 in about ten years. In consideration, the possibility that the price of an electric vehicle using a lithium ion battery will fall in a short time cannot be dismissed.

3. CONCLUSION

(1) Transition of a period until the diffusion rate will be 20 % from the sale start and price was analyzed for consumer electronic products of various forms created with new technology. As a result, it has already been shown clearly that the character of the key device exerts a great action on the earliness of the diffusion of the products which use it, and also transition of price. The character means whether the engineering development of the key device is performed through cooperation of manufacturing and selling or whether it is carried out by the device fabrication side independent of the apparatus manufacture side.

(2) The market of the world automobile industry included a new start by the domestic passenger auto industries of Germany, Japan, and South Korea after World War II. Transition of a period until cars of each country became 20 % of a diffusion rate from the sale start and also the price was investigated. As a result, similar to the analysis result of consumer electronic apparatus, it was discovered that the earliness of spread and price transition is greatly influenced by the character of the engine which is a key device. A possibility that the earliness of the diffusion of cars and transition of price could also be predicted from the character of a key device became clear.

(3) A possibility of following the earliness of spread and price transition of new cars in the future according to the following tendency is high. The main points are as follows.
   (a) When the device fabrication side performs engineering development of a key device independently, the earliness of the diffusion of products was decided by the development speed of the device side. It was an average of five years during the period until it spreads to 20 % from sale start in the case of consumer electronic apparatus.
   (b) When the key device manufacture and apparatus manufacture side cooperate and perform engineering development of a key device, the earliness of the diffusion of products was decided by the speed of apparatus development. In the case of consumer electronic apparatus, it was an average of nine years. In the case of the car, it was an average of 14 years.
   (c) When the key device manufacture side carries out independent production and sales of the key device or the apparatus manufacture side produces in-house, the real price ratio of products becomes about 50 % or less of the prices of sale start time. A real price ratio means the value which normalized the price ratio by the growth of GDP per person at the time of sale start and 20 % diffusion.
   (d) When performing the production and sales of a key device exclusively by close cooperation with the apparatus manufacture side, the function of products improves and the tendency for the price not to fall is seen.

(4) The key device of an electric vehicle is the battery. The earliness of spread and price transition is presumed as follows from the character of a battery.

(e) Development of the electric vehicle which is aimed at replacement of a common vehicle was performed on the basis of close cooperation between a battery maker and an automaker. Production and sales were prepared together and cooperation on development of vehicles and development of a battery were also performed. Therefore, in this case, it becomes (b) and (c) of the conclusion 3. However, since the price was very high compared with a common vehicle and also the low mileage by one charge, the diffusion itself cannot be expected and it is not the subject of this prediction.

(f) If the problem of mileage and the price is solved, engineering development of a battery will be independently performed by the battery maker, and it is expected that production and sales will also be performed independently. In that case, the earliness of the diffusion of electric vehicles is decided by the development speed of the device side, and is expected to be very fast. Furthermore, it is expected that the fall of the price of products will also be very fast.

(5) New application of an electric vehicle may expand a new market, and may lead to the mass production of a battery. The demand produces the volume efficiency of a battery and a possibility of reducing the outstanding problems of an electric vehicle cannot be denied.

Acknowledgements

This research was carried out under advice with Professor Shigeyuki Minami of the Osaka City University.

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(Received October 30, 2009; accepted December 1, 2009)