B-55.1 Studies on clarification of problems caused by widespread of electric vehicles and their measures (Final Report)

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Total Budgets for FY1997-1999 87,921,000 Yen (FY1999 21,993,000 Yen)

Abstract

This study aims at evaluating the compact electric vehicle (EV) already developed, clarifying problems and their measures caused by the widespread of electric vehicles and estimating the possibility and CO_2 reduction effect by future EVs. The contents are as follows.

An on-board monitoring system was developed to measure energy consumption and EV performance. The vehicle was evaluated by trial drives on a test course and on the chassis dynamometer with developed monitoring system. The acceptability of EVs was investigated and valuable information for introducing EVs into the market was obtained by the questionnaire surveys in Japan, US, Belgium and China. The simulation study for performance and drive system and the design for future vehicle concept were carried out. The new EV technology on drive system was examined. The possibility of introduction of EVs was estimated based on actual vehicle use. It is found that about 90% of gasoline vehicles in Kanto region can be changed to EVs.

Key words Electric Vehicle, Luciole, In-Wheel Motor, Battery Built-in Frame

1. Introduction

About one quarter of CO_2 emission in Japan is originated from transport sector and about 90% of which is caused by automobiles. Moreover, 20% of CO_2 emission around the world is from transport sector and its amount is increasing over 3% per year. Most of these emissions is caused by vehicle traffic in urban areas. In order to arrest global warming, measures in urban transport sector are very important.

Therefore, it is necessary to make alternative fuel vehicles such as EV more practical at lower cost. And it is required to examine the introducing scenarios and to estimate the cost-effectiveness for those measures, after imagining future urban transport system where many alternative fuel vehicles will be available.

2. Research Objective

This study aims at 1) evaluating the compact EV named "Luciole" already developed by the

National Institute for Environmental Studies in 1996, as an example of future EVs and 2) clarifying problems and their measures caused when lots of this type of EVs will be in the society and 3) estimating the possibility and CO_2 reduction effect by future EVs.

3. Results and Discussions

3.1 Overview of test vehicle

The test EV "Luciole" was developed to address urgently various problems by the car society; air pollution, wasteful energy consumption, traffic safety and congestion. Luciole is high performance, lightweight EV for convenient city commuting. Equipped with the latest technology, such as an in-wheel motor drive system (IWDS), a battery built-in frame (BBF), and an advanced battery management system. Luciole realizes an advanced EV concept. Even though the vehicle is smaller than a standard Japanese mini-car (W*L*H; 1.48m*3.4m*2m), it provides roomy passenger space and extra safety against the side impacts because of its unique in-line passenger seating. Maximum speed of the Luciole is 150km/h and 0 to 40km/h acceleration time is 4.3 sec, 0 to 400m acceleration time is 17.9 sec. It is superior to Japanese mini-car from every angle and also fully competitive to internal combustion engine vehicles. The photo of Luciole is shown in Figure 1.

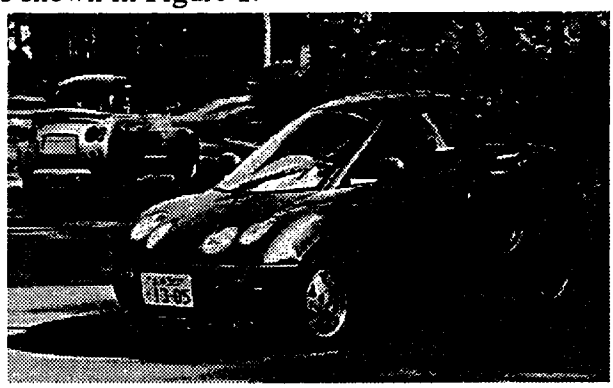


Fig. 1 Photo of compact electric vehicle "Luciole"

3.2 Evaluation of the vehicle

3.2.1 Photovoltaic cell system

The test vehicle Luciole equipped with a polycrystalline photovoltaic (PV) cell of 67W at roof and rear spoiler to assist battery charging and/or compensate self-discharging of battery. To estimate its effectiveness, the experiment of electricity generation and transfer efficiency for PV system was carried out. As the result of measurement, energy transfer efficiency from solar energy input to battery input was about 3.2%, although the efficiency from solar input to PV output was 10.6%, which is equivalent to the catalogue specification. It is found that the DC/DC converter which converts PV output voltage to battery input voltage was not designed more effective.

3.2.2 Development of an on-board monitoring system for EV

An on-board monitoring system was developed in order to measure frequently changing

current, voltage and electric power of battery output, motor input and motor output torque on driving a vehicle.

Figure 2 shows the configuration of the monitoring system. This on-board system enables us with high time resolution to retrieve 1) detailed electric power consumption and travelling distance, 2) transient characteristics of inverters and motors, 3) charging and discharging efficiency of battery at the vehicle in use or not.

Figure 3 shows an example measured at 15 mode driving by the monitoring system.

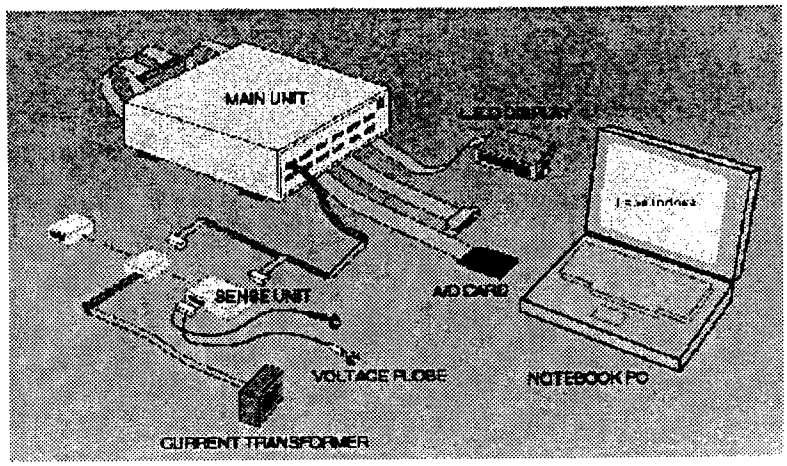


Fig 2. Configuration of an on-board monitoring system

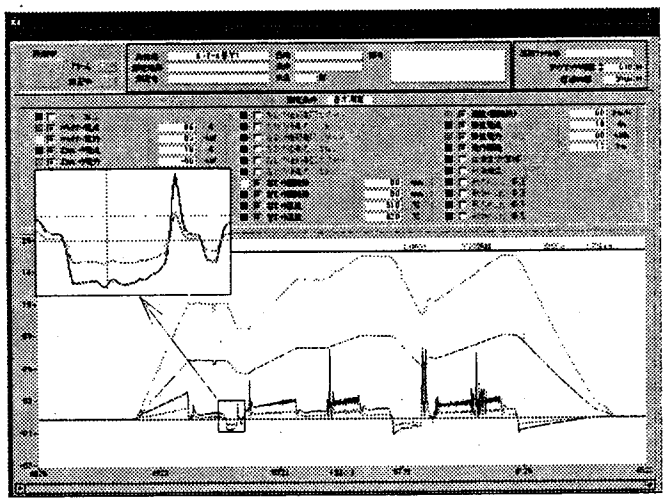


Fig. 3 An output example at Japanese 15 mode driving

3.3.3 Simulation analysis of the vehicle

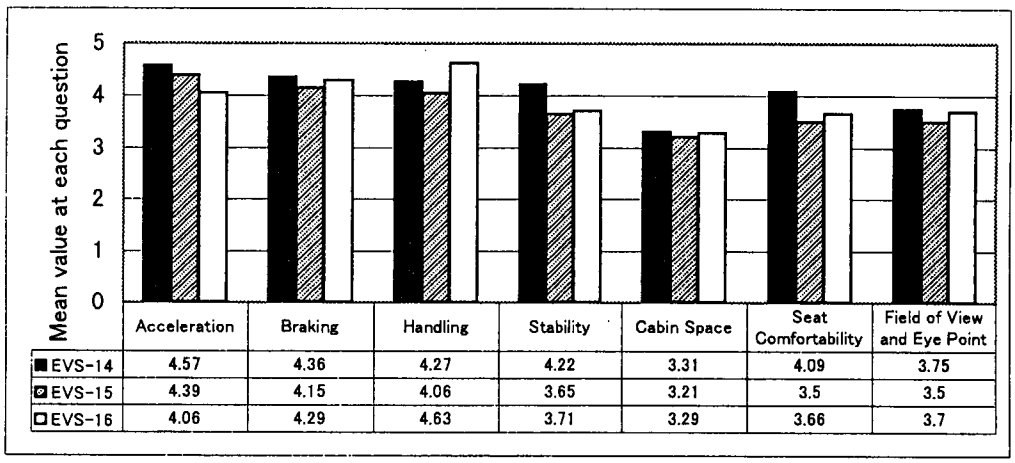
The simulation programs for evaluating EV performance in advance before the vehicle will be made and stability of the chassis and suspension system with the IWDS as well as conventional drive system were developed.

Modeling and analysis of suspension system was conducted using the DADS language that is popular in the research field of mechanical engineering. The effect on stability of making the weight of IWDS lighter than present was examined. It is found that the stability on driving a vehicle largely depends on rather the setting of suspension parameters than the weight of drive system.

3.3.4 Questionnaire survey of public acceptance for Luciole

It is important to examine the vehicle by various people in the real world and to know various comments in order to reflect the development of the next generation car with wide acceptance from the society. To search the feasibility in the market from the public, Luciole was exhibited and driven at the test drive-course on the occasion of the 14th, 15th and 16th international electric vehicle symposium (EVS-14,15,16) in 1997 to 1999 in US, Belgium and China, respectively. 343 participants filled out the questionnaire and were interviewed on driving performances, comfortability, exterior and interior design and consumer interest of the Luciole after their test drive.

Figure 4 shows the mean value of the evaluation of the Luciole, where answers are scored such as 5 for "Very Good", 4 for "Good", 3 for "Average", 2 for "Not Good" and 1 for "Bad".



	Acceleration	Braking	Handling	Stability	Cabin Space	Seat Comfortability	Field of View and Eye Point
■EVS-14	4.57	4.36	4.27	4.22	3.31	4.09	3.75
▨EVS-15	4.39	4.15	4.06	3.65	3.21	3.5	3.5
□EVS-16	4.06	4.29	4.63	3.71	3.29	3.66	3.7

Fig. 4 Evaluation of Luciole on performance and design at each EVS

The mean value of the all participants rated 4.4. More than 90% of the participants evaluated acceleration of the Luciole as "Very Good" or "Good". There was no answer that the score is 2 or 1.

More than 90% participants showed strong interest in the acceleration and vehicle design. About 70% stated that tandem-seat layout adopted to Luciole was fantastic. Most participants answered that Luciole was suitable as a commuting car.

The results of performances and design and comfortability evaluation of the Luciole were perceived practical and attractive from the participants. Cabin space evaluation was depended on the physiques of the participants.

As of consumer interest, about 70% of total participants answered that they would buy the Luciole as shown in Figure 5. Figure 6 shows the price range by participants who would buy the Luciole. About 50% of the total participants expected the price in the range of $5,001 to $10,000. But about 20% of respondents told that Luciole has higher value than mini-car.

Similar surveys were conducted at festivals on low emission vehicles or environmental issues in Japan.

Luciole were fully accepted from the public. EVs like the Luciole has large potential to be accepted in the society.

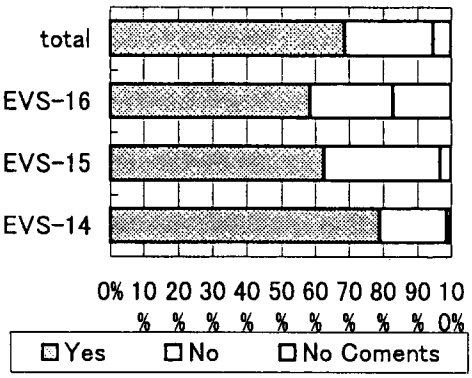


Fig. 5 Interest in purchasing the Luciole

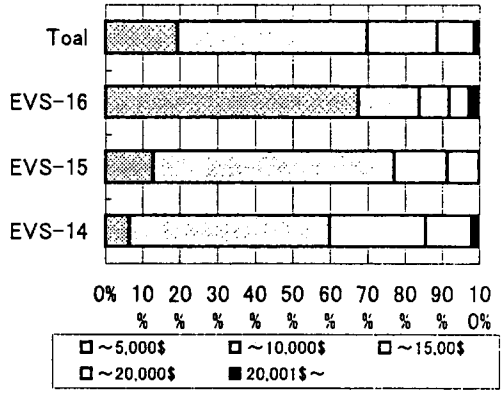


Fig. 6 Price range suggested by participants

3.3.5 Concept of future vehicle

Luciole is high performance electric commuter due to make good use of EV characteristics and technologies. When we surveyed Luciole's acceptability, much portion of respondents asked, "Can you make sedan type EV with the concept applied to Luciole?". Therefore, we think that the demand for sedan type EV is much and people are willing to have a strong interest in that EV. To realize this, it is necessary to examine vehicle concept, to improve performances of and/or redesign the motor drive system and tyres. So, new IWDS was designed as it becomes more effective with higher performance and the possibility of IWDS with steering system was examined.

Figure 7 shows the future vehicle concept with IWDS and battery built-in frame (BBF) structure. Vehicle chassis system is consisted of IWDS and BBF. Its upper part is exchangeable with several types of cowls as the driver needs.

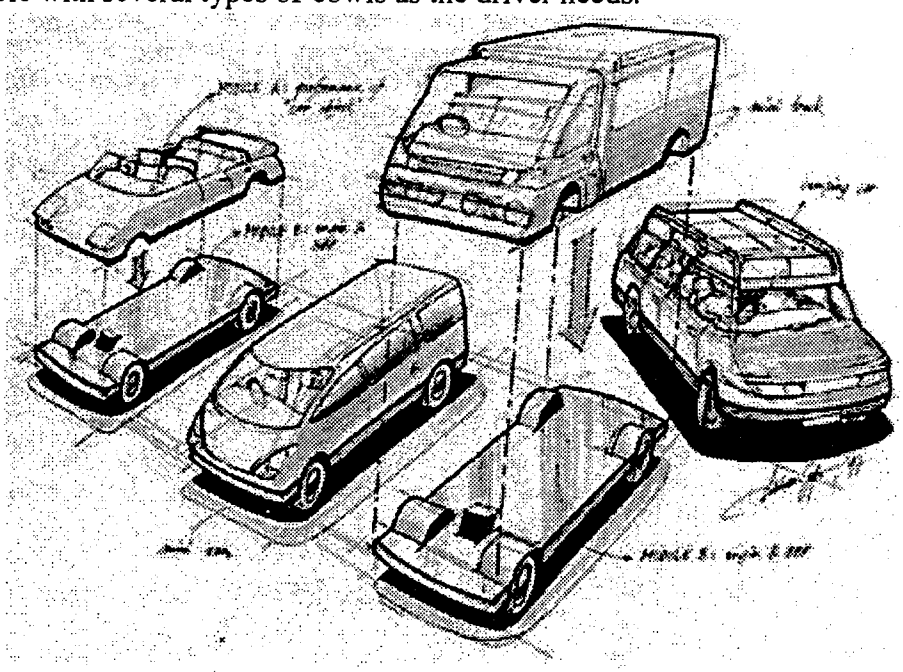


Fig 7 Future vehicle concept with IWDS and BBF.

3.3.6 Estimation of the possibility and CO_2 reduction effect by introducing EVs

Life cycle CO_2 assessment of EVs like Luciole was conducted on how many vehicles we can change to EVs and how much CO_2 can be reduced, taking EV's disadvantage of short travelling distance into account. The I-O table was used to calculate CO_2 emission[1] at production of vehicle. Data on actual vehicle use was taken from the report[2] investigated in 1997 in Kanto region by JCAP (Japan Clean Air Act)/PEC(Petroleum Energy Center) and it was used to estimate substitution effect of vehicle at use stage.

Estimation of CO_2 reduction by substituting EVs was carried out on passenger cars and mini-trucks by type of use as private use or commercial use. The travelling distance for EVs was assumed the Luciole's data. The amount of life cycle CO_2 emission was divided into one year amount by the lifetime of a vehicle.

As the result of estimation, EVs have the possibility to substitute for about 90% of 17.6 million gasoline vehicles (GVs) registered in Kanto region. The reduction amount per vehicle is changed 3 times by size or by type of use. If all possible GVs in this region change to EVs, the reduction amount of CO_2 corresponds to several million ton of carbon per year.

4. Conclusion

Clarification of problems and their measures caused by the widespread of electric vehicles was carried out by selecting Luciole as a test vehicle, developed in 1996 by the National Institute for Environmental Studies. To evaluate the EV performance more in detail, an on-board electrical performance monitoring system was developed. The simulation programs were developed to analyse the performance and stability of the drive system. Public acceptance of EVs was investigated and valuable information was obtained by the questionnaire survey at domestic festivals on low emission vehicles or environmental issues and at international EV exhibitions. The new EV technology on drive system was examined. The possibility of introduction of EVs was estimated based on actual vehicle use. It is found that EVs can substitute for about 90% of GVs in Kanto region.

References

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2)JCAP/PEC, PEC-1997-TA22, 200pp, 1998.3.