EVS27
Barcelona, Spain, November 17-20, 2013

The Study of EV Data Collection and Analysis based on Taiwan i-EV Pilot Project

Yi-Ching Lee[1], Wen-Hsien Hsu[1]
[1] *Automotive Research & Testing Center, No.6, Lugong S. 7th Rd., Lukang, Changhua County Taiwan, jean@artc.org.tw,wilsonhsu@artc.org.tw*

Abstract

The evaluation data of EV in motion or in charging is a new research to reveal the EV performance and user behaviour. ARTC (Automotive Research & Testing Center) is devoted to the study of EVs for years, and in charge of the data evaluation in Taiwan i-EV pilot project. With the project's purpose, ARTC designs the flow of this task. First of all, the data need to be gathered including status, speed, date/time stamp, battery SOC on the vehicle are automatically transferred to OBU (On-Board Unit) through CAN protocol. The OBU developed by ARTC sends the data via 3G/GPRS to data collection platform. Afterward, the data are processed and analyzed by statistical method to address the results such as the driving distance, the distribution of the battery SOC etc. There are two operational models from the EV pilot projects at megalopolises in Taiwan. One is service car for public affairs and the other is rental car for the public. The data present the differences between various areas and purposes. The outcomes can help the government to make policy, fleet to earn the largest benefits, and car factory to adjust the car design.

Keywords: EV(electric vehicle),CAN (controller area network),OBU(On-board Unit)

1 Introduction

Under the pressure of energy shortage and environment pollution, more attention has been paid to decrease the carbon emission and oil consumption. In the vehicle industry, EV (Electric Vehicle) is one solution to solve these problems. Therefore, the car manufacturers around the world make efforts in developing EV. Several EVs are released like Luxgen7 MPV EV+, Tobe W'car EV, Tobe M'car EV, Tesla Model S, Nissan Leaf, Toyota iQ, Mitsubishi i-Miev, BMW Mini-E, etc. However, the popularization of EVs is restricted by driving range, charging stations and vehicle's price. The car manufacturers are striving for breaking through these restrictions. In the meantime, governments and institutions worldwide are implementing the EV trial projects to collect the data when the car is in use and evaluate the data.

1.1 Promotion Strategy of electric transportation in Taiwan

Taiwan has a niche in batteries, parts and other industries that are essential in the development of EVs. Taiwan is characterized by small terrain, dense population, and little distance between cities. With geographical features and industry superiorities, Taiwan has the great advantage of developing EVs and EV operation. Therefore, Taiwan government exerts great effort to promote Electric transportation.

In the e-scooter field, the government raises the strategy to promote e-scooters.

- The government approves Taiwan E-scooter Standard (TES), the first standard of e-scooter in the world.
- A pilot zone is set up in Penghu. Penghu is an island where there are many travellers visit here. The pilot zone is not only for residents but also for the travellers.
- Government subsidy is provided when customer purchases the e-scooter.
- Make the e-scooter component localization.

In electric vehicle field, the government published the "Intelligent Electric Vehicle Development Strategies and Action Plans" in April, 2010 to enhance the EV industry. The strategies including as below:

- The tax exemption will be phased in during a 3 year period, beginning Jan 28 2011, resulting in a complete exemption from commodity tax for EVs, which was originally 25%.
- The 3-year licensing-free policy was also announced for EVs.
- The limitation of fuel economy was raised 10% from Jan 1 2012.
- The government also plans to take measures to control the volume of carbon emission.

1.2 Taiwan i-EV Pilot Project

The Development of e-scooter in Taiwan is satisfactory. With the e-scooter's experience, the government starts to promote the electric vehicle. One of the approaches in "Intelligent Electric Vehicle Development Strategies and Action Plans" is to perform Pilot Run Project.

Taiwan i-EV Pilot Project runs in the metropolitan areas in Taiwan. The EVs are used as the government cars and rental cars. The main purpose of government cars is to show EVs to the Public. They are used as shuttle bus between the government buildings or squad cars. The rental car can be rented by the Public. It helps the Public to approach and understand EVs.

So far, there are more than 250 electric vehicles running and about 300 chargers are set up. Moreover, those EV are running in four areas of Taiwan. The detail information of each project is as following:

- The EVs in Taipei is for rent by the Public. The vehicles in this project are Luxgen7 MPV EV+, Tobe W'car EV, and Tobe M'car EV, three of the car types are localizations in Taiwan. Luxgen7 MPV EV+ is a 7-seat vehicle for family trip, and Tobe EV is 4-seat. Users can rent EVs to travel around Taipei.
- The EV's usage in Taichung is government car. There are two car types running in this project, Nissan Leaf and Luxgen7 MPV EV+. Luxgen7 MPV EV+ is as shuttle bus, and Nissan Leaf is for user in government department who is on a business trip.
- The same as Taichung, the EVs in Tainan is also for government car. However, all of the EVs are for officers on a business trip. Luxgen7 MPV EV+ is the only car type in this project.
- Sun Moon Lake is a famous scenic area in Taiwan. The rental company plans the pilot project in this area. The cars in this project is for rent by car-sharing service. The car types here are Toyota iQ EV and Toyota Prius. The government expect the area will be a clean area with the pilot project's experience.

The Taiwan government endeavour to promote the pilot projects to the other place in Taiwan. By the experiences of four pilot project, the government and manufacturers obtain helpful suggestions to popularize the EVs in Taiwan, make policy reference, and improve vehicles.

2 Related Work

There are several EV trial projects around the world like EV Project in U.S., CABLED in U.K. and Shanghai International EV Demonstration Zone in China, etc. The following subsection will describe the data collection and analysis of these EV trial projects.

2.1 EV Project

The EV Project is the largest deployment of electric vehicles and charging infrastructures in history. The purpose of this project is to build and study mature EV charging infrastructure in U.S. regions.

In EV Project, the data from vehicle including vehicle status, battery SOC, date/time stamp, GPS are logged per trip and the data from EVSE (Electric Vehicle Service Equipment) like date/time stamp, connect and discount times, start and end times, maximum instantaneous peak power, total energy per charging event. The analysis is to address the average distance per day or between charging, the usage of each charging station, etc. All of the result is to evaluate the

locations and the numbers of chargers if they are appropriate or not.

2.2 CABLED

The CABLED project collected data from the vehicles to understand how they were used in real life and to assist in the planning of the further expansion of the supporting infrastructure. The result in this project can be gained like frequency of individual journey, length and duration of journeys, date and time of journeys, energy used per journey, location of charging/ parking, average speed, etc. The results are to improve the design of EVs and the location of EVSE.

2.3 Shanghai International EV Demonstration Zone

Shanghai was declared as EV international pilot city and Jiading as EV international demonstration zone by the Chinese government in January, 2011.

The data as data/time stamp, odometer, GPS, event info, charging info are recorded. The analyzed items are driving distance, driving duration, charging habits, etc. The driving data collection in this project is to confirm the driver's security, the acceptability of EVs, and the practicability of EVs.

3 Data Collection and Analysis in Taiwan i-EV Pilot Project

To evaluate the Pilot project's performance, the first step is to make the operational plan. Next step is to establish the model that is what and how to evaluate. Data capturing and processing are following the first two steps. It continues the final steps, verify the outcome and produce the report. The flows are shown on Fig.1.

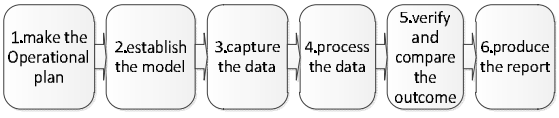

Figure1: The flow of data evaluation

Taiwan i-EV Pilot Project collects and analyzes the EV data to evaluate the user's driving and charging habits, and infrastructure appropriateness of EVs. The goal of this project is to gain the constructive suggestions to make policy and popularize EVs. Based on the goal, ARTC brings up the method to collect EV data in motion and in charging. The detail contents are as following:

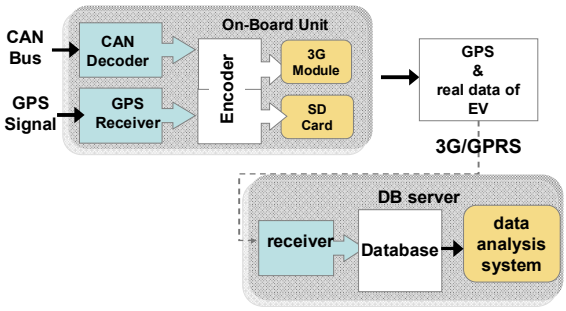

Figure2: The flow of data collection and analysis

3.1 Data Collection

Fig.2 shows that OBU can collect the data from EV. The OBU needs to be fitted on the EV. The data on the vehicle are transferred to OBU through CAN protocol. Then, the data are sent to the data system via 3G/GPRS or stored in the card. There is another method doesn't show on the Fig.2. The method is manual log is written down by drivers. The data parameter and the frequency of two methods are appeared as Table1:

Table1: The method of data collection

	recorded by drivers	recorded by OBU
data parameter	date/time mileage battery SOC destination	odometer battery SOC speed date/time stamp event info location
frequency	recorded per trip	recorded per second

Data-collection method may cause the value out-of-range, data missing, and impossible data combination. It will make "garbage in, garbage out", so the data need to be pre-processed after storing in the database. The flow of pre-process will make the data correct and reasonable.

- Correct the data is out of range: The data from the car have the boundary like the range of SOC is between 0 and 100, the speed depending on the car designing, etc. The data will be detected according the limitation and removing outliers.
- Handle the missing data: Some records are missing because of internet and device. If

possible, the missing data could is filled manually, otherwise the data will be ignored.

After this step, the data will start to be analyzed.

3.2 Data Analysis

The raw data are stored on the database are classified according to the vehicles' status. They are divided into two conditions, driving data and charging data. They are processed to the information per journey as start/end time, start/end battery SOC, driving distance per trip or between charging, etc. The evaluation algorithms as driving habit analysis and car performance analysis are applied to the step after data classification. Taking some examples, by observing the concerns from the public, the government, the vehicle factory and fleets, ARTC addresses the items such as the difference of carbon emission between the vehicle with ICE (internal combustion engine) and EV, the distribution of battery SOC at the start/end of charging, and driving distance to help people who are interested in EVs to understand the development of electric vehicle, the appropriateness of infrastructure, and the acceptability.

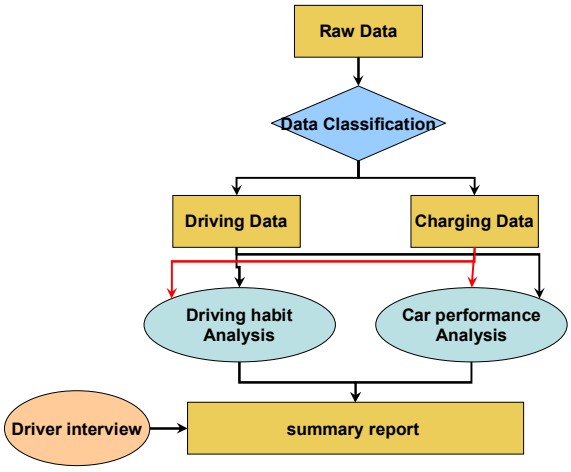

Figure3: The flow of data analysis

3.3 The comparison of the data evaluation method between Taiwan i-EV Pilot Project and pilot project in the world

Table2: data parameters collected in pilot projects

parameter	Taiwan i-EV Pilot Project	the EV Project	CABLED	Shanghai International EV Demonstration Zone
event info	v	v	v	v
date/time	v	v	v	v
odometer	v			v
speed	v		v	
battery SOC	v			v
location	v	v	v	
external temperature			v	
EVSE info		v		

Table3: analysis result in pilot projects

parameter	Taiwan i-EV Pilot Project	the EV Project	CABLED	Shanghai International EV Demonstration Zone
the mileage per trip/day or between charging	v	v	v	v
the distribution of speed per trip	v	v	v	v
the distribution of starting time per trip	v			v
the distribution of battery SOC per charging event	v	v		v
charging frequency per day	v	v		v
the distribution of starting time per charging event	v			v
carbon emission	v			v

The parameters in these pilot projects are event info like the vehicle is key on, key off, or in charging, date/time stamp, odometer, speed, battery SOC, location, external temperature, and EVSE info. Taiwan i-EV Pilot Project focuses on vehicle's data. The EV Project's purpose is to figure out the charger is appropriate or not, it

emphasized the information of EVSE. The purpose of CABLED is the same as the EV Project, but CABLED analyzed by driver habit instead of information from chargers. Shanghai International EV Demonstration Zone is similar to Taiwan i-EV pilot project, and the contents of the report are described about the driver habits and the vehicle's performance.

4 The analysis result in Taiwan i-EV Pilot Project

In Taiwan i-EV Pilot Project, 20% of EVs and all types need to be selected from each pilot area, and the selected vehicles need to provide the information when they are in motion or in charging. By the data collected and analyzed, the result can help to improve the vehicle design, adjust the location of charging station, and provide the policy reference.

There are 4 pilot projects in Taiwan until June, 2013. Two of them are for government car in Taichung and Tainan. The others are rent car for the Public. The areas are in Taipei and Sun Moon Lake. The following result shows two projects start from 2012 because of the amount of data, and the result focused on the driving habits:

Table4: Project information

		Project a		Project b
car	type	A	B	C
	quantity	10	10	20
	range	100km @LA4	179km @LA4	160km@LA 4
	weight	1111kg	2010kg	1520kg
	battery capacity	16 kWh	45 kWh	24 kWh
usage		rental car		government car
area		city/suburb		city

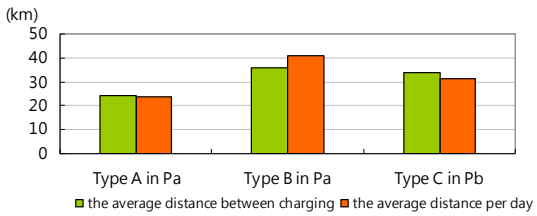

Figure4: The average distance of the projects

There are three points appearing on Fig.4.

- The distances cars ran are proportional to the battery capacity. The average distances between charging and per day are similar. This phenomenon infers the cars are charged once per day, and the charging locations are the destination.
- The distances users use are less than the range of the car, for example, the range of type A is 100km, and the average distances between charging user uses are about 25km. There is a large difference between the distance user uses and the car's range.
- At this stage, the chargers are enough. However, user didn't fully utilize the battery. User may have range anxiety, or limit to the usage.

Table5: the usage of battery

	Project a	Project b
average energy consumption per day(kWh)	A:7.55 B:17.71	6.29
battery SOC at the start of charging	63.26%	60.90%
battery SOC at the end of charging	94.69%	92.73%

From Table5 and Fig.4, the values of energy consumption are obtained.

- TypeA: The average distance per day is 24.23km, it's estimated that the energy consumption is 3.21km/kWh.
- TypeB: The average distance per day is 43.93km, it's estimated that the energy consumption is 2.48km/kWh.
- TypeC: The average distance per day is 6.29km, it's estimated that that the energy consumption is 4.92km/kWh.

Type B is the heaviest, and the energy consumption is more than the others.

The battery SOC at the start of charging is more than 60% in two of the projects. The outcome concurs with the result of Fig.4. User didn't fully utilize the battery because of range anxiety and usage limitation.

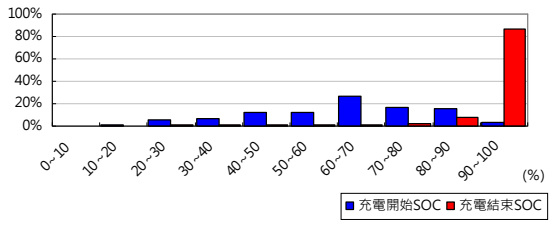

Figure5: battery SOC when charging in Project b

Fig.5 shows the distribution of battery SOC when charging in Project b. Type C shows low battery warning when batter SOC is about 16%, and only 6% of charging events start to charge when the battery SOC is lower than 20%. Over 85% of charging events end to charge when the battery SOC is higher than 90%, and 10% of charging events are terminated when the battery doesn't charging to the battery's full capacity. The battery SOC at the end of charging is more 90%, and it shows that user has enough time to charge.

Table6: average speed of projects

	Project a	Project b
average speed(km/h)	A:17.04 B:17.73	14.98

The maximum speed in city in Taiwan is 50 km/h, and the minimum speed in freeway in Taiwan is 80km/h. Table6 appears the average speeds of two projects. It's derived that the areas EVs run are always in the city hence the average speed is slow.

The detail distribution of average speed in Project b is as Fig.5. The average speeds of trip are Over 90% lower than 30km/h. The result shows that EVs in this project always runs in the city. It's indicated the government car always runs in the city or users driver EVs only when the trip in the city.

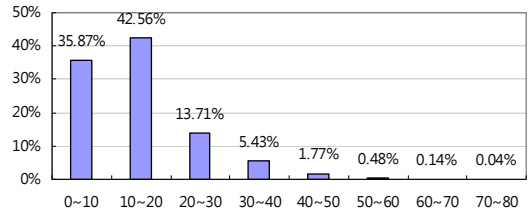

Figure6: the distribution of speed in Project b

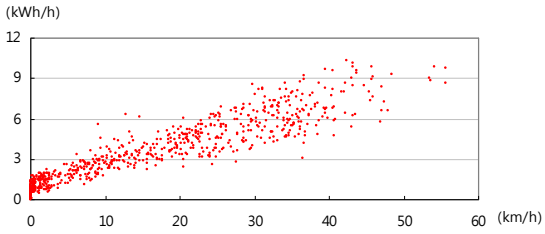

Figure7: the relation of speed and energy consumption

One car L is selected to show the relation of the average speed and energy consumption in Project b in Fig.7. The meaning of x-axis is the average speed and the definition of y-axis is the energy consumption per hour in Fig.7. With Fig.6, the result EVs runs in the city in Project b is obtained, and the terrain is considered flat. EVs are in the project b is for government. Car L is for one of the department, it's assumed the driver's habit is similar. Fig.7 appears that the energy consumption is directly proportional to speed when the speed is from 0 to 60 km/h. Driving EVs in the suburb consumes more energy that in the city.

One important index of electric transportation is carbon reduction. The carbon reduction is the difference of carbon emission between the ICE and EV. Taking the type C in project b for example, the average distance and average energy consumption per day are 31.30 km and 6.29kWh. The carbon emission of ICE is 4.72kg, and one of the EV is 3.37kg. The ration of carbon reduction is 28.60%.

From the above section, it's obtained that the drivers use the EVs has range anxiety because they don't fully utilize the EVs. The main reason if that users lack confidence in EVs. The government need to force the car manufacturer to improve the EVs and instruct the Public how to use the EVs to make EVs have the maximum effort.

5 Conclusion

Taiwan government aggressively promote the EVs. By i-EV pilot projects, the Public understand EVs more; the EV industry catches the data to improve the car design, and the government can get information to be the reference as making the policy.

The projects' results show the driver habits are addressed as following:

- The average driving distance per day is around 40 km/h, and the driving range is

bigger than 100km/h, user in these projects didn't fully utilize the vehicle's range.

- The battery SOC is bigger than 60 when most charging events are started by user. User didn't fully utilize the battery because of range anxiety and usage limitation.

With the results, the EV drivers didn't fully utilize the vehicle. At present, the distances user drives don't reach the car's driving range and the battery SOC when starting to charge is over 50%. All of these appearance shows the Public have less reliance on EVs. The government need to instruct the Public how to use EVs to make them have the maximum effort.

With Taiwan pilot projects, the EVs are on public display, and the public can drive the EVs in practice. The public can experience the advantages of EVs, and provide the driving data to the government adjust and make the policy to popularize the EVs and let the public accept the EVs more. The EV industry realize what users need and improve the car's design to be suitable for users. By promoting EVs, decreasing the carbon emissions and oil consumption to build a cleaner country.

References

[1] Bing-Ming Lin, Shiow-Huey Suen, Jason Shian-Ching Jang, *Promotion Strategy of Electric Scooters in Taiwan,* Journal of EVS24, ISSN 2032-6653

[2] *Energy Smart Communities Initiative,* http://esci-ksp.org, accessed on 2013-01-04

[3] *Pilot Project for intelligent E-cars, Ministry of Economic Affairs, R.O.C,* http://www.lev.org.tw/iev/index.aspx, accessed on 2013-01-04

[4] *The EV Project*, http://www.theevproject.com, accessed on 2013-01-04

[5] *CABLED Project*, http://cabled.org.uk , accessed on 2013-01-07

[6] *EVZONE ShangHai China*, http://www.evzonechina.com , accessed on 2013-01-07

Authors

Miss Yi-Ching Lee
The researcher studies the data analysis of EV in Taiwan i-EV Pilot Project.
Her experiences are data collection, statistical data analysis and reporting.

Mr. Wen-Hsien Hsu
Wen-Hsin Hsu has over 15 years experience in the automotive industry specializing in service model research and systems engineering. He is also the leader of group does the evaluation data of EV research in Taiwan i-EV Pilot Project.