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Vehicle Management and Travel Data Analysis of E-Bus Adopted in JR Kesennuma Line

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Summary

When putting electric buses into practice in mass transit systems, the vehicle state management becomes a vital factor in the realization of a stable commercial operation. Aiming at achieving a sound bus operation, we installed a vehicle monitoring system on our own conversion E-Bus and realized remote vehicle control and driving data logging. In this manuscript, we are presenting a track record of the E-Bus and the vehicle monitoring system introduced in the JR (Japan Railway) Kesennuma Line which was severely hit by the Great East Japan Earthquake on March 11, 2011 and later temporarily restored as the BRT (Bus Rapid Transit).

Keywords: BEV (Battery Electric Vehicle), bus, Japan, maintenance, public transport

1 Introduction

East Japan Railway Company (JR-East) started operation of BRT on 2 bus-lines such as Kesennuma Line; from August 2012, and Ofunato Line; from March 2013, as the temporarily restoration of bus-lines in the coastal disaster area severely hit by the Great East Japan Earthquake on March 11, 2011. In April 2014, JR-East introduced an E-Bus (the “e-BRT”) for commercial operation on BRT Kesennuma Line between Motoyoshi and Kesennuma bus stops with an aim to support the reconstruction by contributing to environmental load reduction and tourism in the said disaster area.

2 Operation section of the e-BRT

The e-BRT operates on a section between Motoyoshi and Kesennuma where specifically the largest numbers of passengers are expected in the JR BRT Kesennuma Line from Maeyachi to Kesennuma (between Yanaizu and Kesennuma at the time of e-BRT implementation, later started practice between Maeyachi and Yanaizu from June 27 2015). Figure 1 shows the operation section. The distance between Kesennuma and Motoyoshi is approx. 22km and the traveling time is approx. 40 minutes.

The e-BRT covers 2 round-trips (approx. 88km) a day over this section. Example of adoption of E-Bus on a bus route that covers a distance exceeding 20km is still very few in Japan.

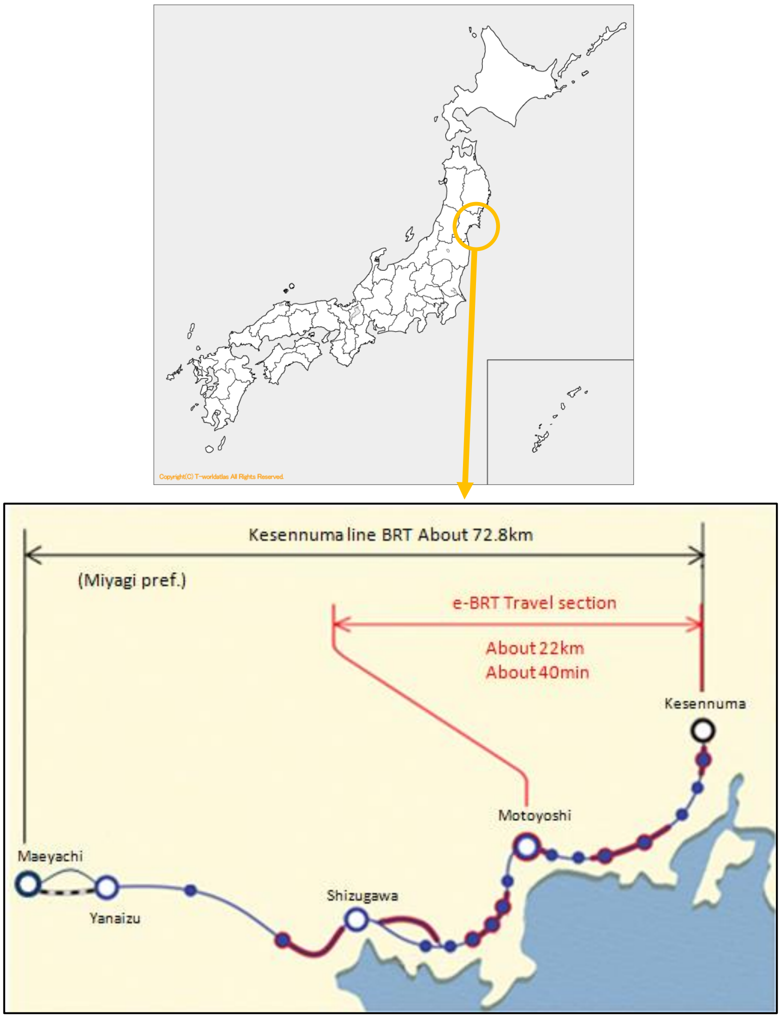

Figure 1: e-BRT operation section

3 Specification of the e-BRT

The e-BRT is a conversion E-Bus based on the mid-sized diesel by Isuzu Motors. The vehicle is equipped with traction battery with the capacity arranged to allow single charge duration of approx. 22km even after 5 years of operation. We formulated the traction battery capacity based on prospective battery deterioration and simulation of power consumption and as a result, we implemented 4 x Li-ion battery packs as the traction battery with a total capacity of 65.12kWh; 16.28kWh each pack, supplied by Mitsubishi Heavy Industries. We located 2 battery packs in the engine compartment, 1 pack on the vehicle roof and another at the rear-most passenger seats location, in order to minimize the need to reduce passenger capacity. By arranging laying out of battery packs and other components in the rear structure of the vehicle, we successfully managed to limit the reduction of passenger capacity by sacrificing only the rear-most seats. Riding capacity including the driver is 49; 20 seated, 28 standing and a driver.

Installation of battery packs with 65.12kWh capacity added 850kg weight to the original vehicle weight of the base diesel bus making the complete vehicle curb weight at 9,160kg. We arranged the traction motor output at 150kW which is equivalent to the original output of the base diesel vehicle, hence, although the vehicle mass has increased, the power performance remains at a level that does not hinder normal traveling.

Traction battery charging corresponds to; rapid charging as per the CHAdeMO standard as well as normal charging by 220V/110V using SAEJ1772 AC charging connector. Rapid charging corresponds to 50kW and normal charging to 6kW. During bus operations, rapid charging is performed after every operation and normal charging is applied only after the bus operation is over.

As a safety measure for low-speed traveling, a vehicle proximity alarm is implemented.

Apart from that, a solar panel with 450W max output is located on the roof as an auxiliary power supply that helps 24VDC system. Also, heat shield films are provided on cabin windows with an aim to improve heating/cooling efficiency and interior lights are replaced with LED lamps as an energy-saving measure. Further passenger services include interior digital signage monitor, BRT network monitor, and USB ports at some passenger seats. 100VAC exterior power supply facility is also equipped to allow traction battery to aid in disasters and 100VAC sockets are equipped inside and outside the cabin.

Interior and exterior of the vehicle is grounded on the design theme which is based on the e-BRT's adoption concept that is to contribute to reconstruction support through adopting environmentally superior vehicle. Figure 2 shows the image of the vehicle interior.

Table 1：Design theme

"You can see and feel that BRT runs on electricity! A harmony of environment and near future" ＋ "To put fun and excitement into practice (a new purposiveness of BRT application)"

Figure 2：Vehicle interior

Figure 3 shows the image of the vehicle and Table 2 presents the vehicle specification.

Figure 3：Vehicle image

Table 2：Vehicle specification

Base vehicle	Manufacturer	Isuzu Motors Limited
	Type / name	SDG-LR290J1 rev, ERGAmio, low-floor bus
Owner of vehicle		East Japan Railway Company
Dimensions (mm)		8,990×2,320×3,270
Riding capacity		49
GVW (kg)		11,855 kg
Duration (km)		30 (SOC30-80％ simulation value)
Motor	Type	Synchronous motor (permanent magnet synchronous motor)
	Max power (kW)	150
	Max torque (Nm)	650
Battery type / capacity		Mitsubishi Heavy Industries' Li-ion battery / 65kWh
Battery charging		200VAC / 100VAC normal charging and rapid charging (CHAdeMO-compliant)
Equipment		450W solar panel, 100VAC sockets, USB ports, diesel combustion heater, heat shield films on cabin windows

4 Vehicle monitoring system

4.1 Vehicle monitoring system summary

The monitoring system installed in e-BRT utilizes an on-vehicle dedicated data processing device that logs various data through a network of on-board devices configured on a CAN Bus and implements a data monitoring system on a cloud system. This system logs approx. 100 types of raw data that are generated by VCU, BMU or junction box and concurrently executes subsampling and compression processing from raw data of a few msec maximum to resolution of 100msec, and uploads the data to the cloud system via 3G network in real time thus making the real time monitoring of high-speed data in a remote environment available. Figure 3 shows the image of the real time monitoring display. Vehicle location information is also logged concurrently to logging the vehicle data allowing real time monitoring of both vehicle traveling location and vehicle conditions. Figure 4 shows the image of the real time monitoring display. The real time monitoring display caters to easily indicate necessary items hence, it allows to indicate only the important data chosen out of enormous data being logged. More detailed time-series data analysis is also available by CSV output.

Figure 4: Real time monitoring

4.2 Vehicle management

A maintenance system utilizing the vehicle monitoring system as shown in Figure 5 helps to support the bus operator and maintenance service provider by remote vehicle management. Actual vehicle monitoring is carried out at Atsugi, Kanagawa. The e-BRT is operated in Kesennuma, Miyagi, which is approx. 600km remote. When receiving a contact indicating an actual occurrence of vehicle failure, the vehicle condition is checked on the vehicle monitoring system, a failure cause examination will be executed and the bus operator and maintenance service provider will be requested to respond. Utilizing vehicle monitoring system allows to execute temporary response in no time.

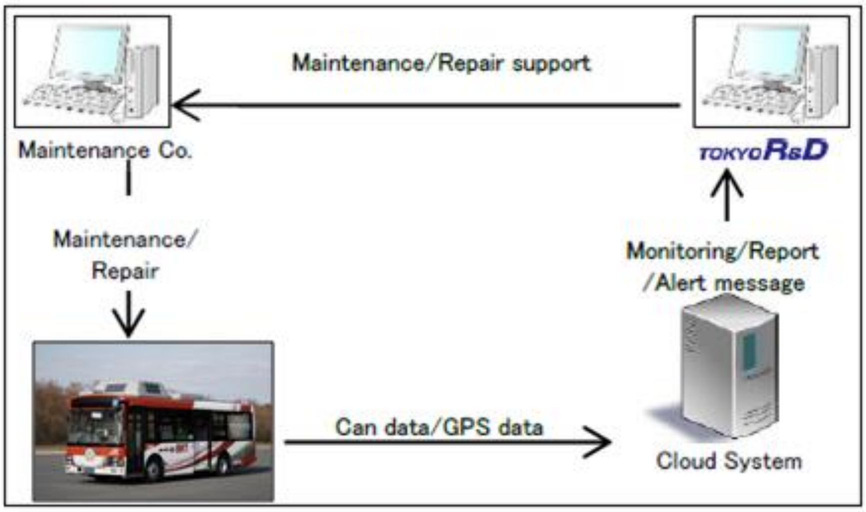

Figure 5: Maintenance system utilizing vehicle monitoring system

Other than the real time monitoring, the vehicle monitoring system function includes a function that distributes pre-arranged items as an operation summary via daily e-mail. This function helps engineers to grasp the basic vehicle condition daily by checking e-mails even without monitoring the vehicle all the time. Such operation summary of e-BRT consists of 10 items distributed in e-mails as shown in Table 2. Figure 6 shows the actual operation summary sent via e-mail.

Table 3：Contents of operation summary

Items	Contents
1	Accumulated traveling time
2	Accumulated mileage
3	Accumulated power consumption
4	Accumulated charging energy
5	Final SOC
6	Max battery temperature
7	Max current
8	Number of rapid charging
9	Number of normal charging
10	Start / end history

2015.02.15
【Today's operation summary】

Accumulated traveling time	12:26:06
Accumulated mileage	85.8km
Accumulated power consumption	84.0kWh
Accumulated charging energy	82.0kWh
Final SOC	92%
Max battery temperature	24℃
Max current	37.6A
Number of rapid charging	6 times
Number of normal charging	1 time

【Start / end history】
2015/02/15 08:19:39 - 2015/02/15 10:14:56
2015/02/15 11:13:32 - 2015/02/15 16:35:15
2015/02/15 16:36:36 - 2015/02/15 21:45:50

Figure 6：Contents of operation summary in e-mails

4.3 Driving data logging

Driving data acquired from the vehicle are retained in the cloud system. Analyzing the driving data helps to understand performance and conditions of the vehicle and to predict subsequent vehicle conditions. We analysed typical characteristics.

4.3.1 Power consumption characteristics

Figure 7 shows the year-round power consumption characteristics.

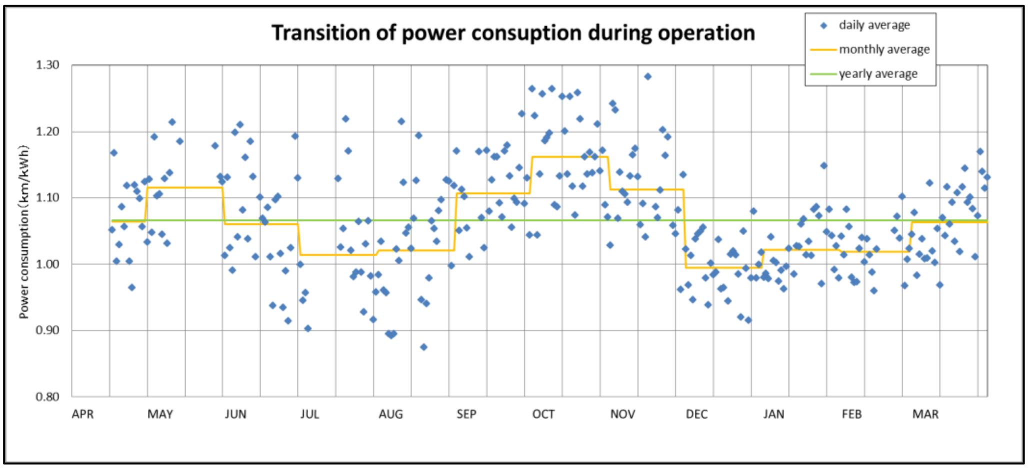

Figure 7 : Power consumption characteristics

Average power consumption was approx. 1.07km/kWh. It shows that the power consumption characteristics tends to run worse during hot season between July and September, and during cold season between December and February. During July-September, the temperature has been over 30 degrees C for many days and it is conceivable that air-conditioner was used frequently. On the other hand, the temperature has been below 15 degrees C for many days during December-February and it is conceivable that deteriorated battery efficiency and poor transportation condition due to snow affected the power consumption. The diesel combustion heater consumes less power as compared to electric heater however it exerts a certain influence.

4.3.2 Relation between air temperature and battery temperature

Figure 8 shows the relation between air and battery temperature.

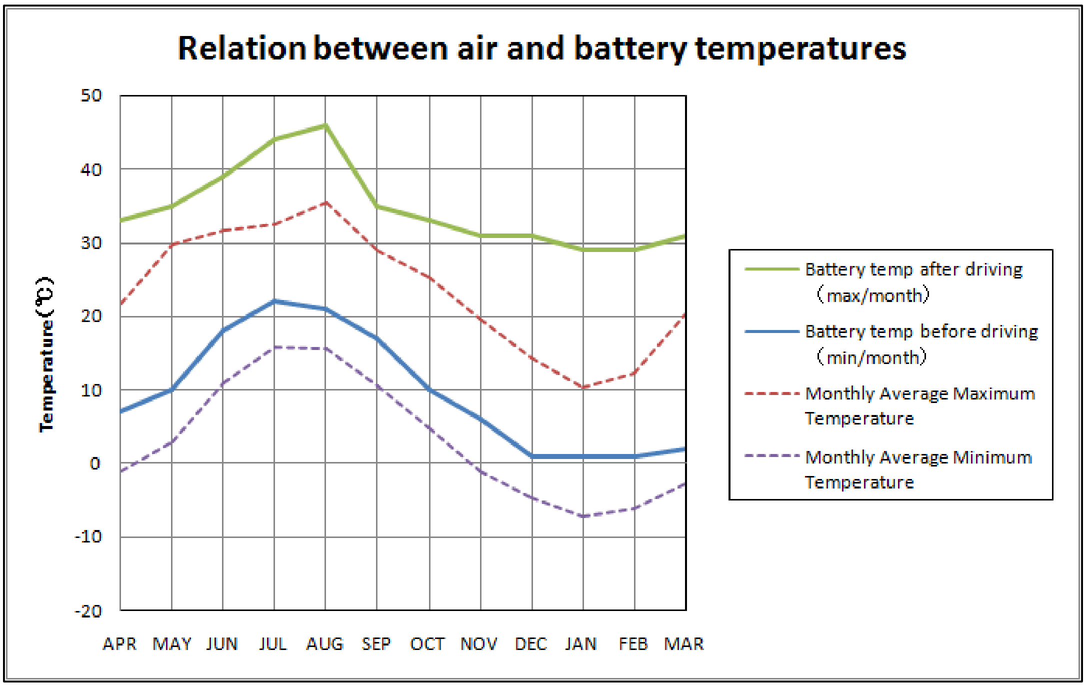

Figure 8: Relation between air and battery temperatures

As read in Figure 8, Kesennuma city has considerable variations in temperature throughout the year. The battery pack by Mitsubishi Heavy Industries adopted this time is air-cooled. Battery pack is cooled by the ambient air therefore it is obvious that the temperature transition is heavily impacted by air temperature. For stable operation, to bring the battery temperature as close as possible to the ambient temperature is vital element. Specification of battery charging / discharging also needs to be kept in mind for operation in an area where temperature variation is considerable. Especially, when the ambient temperature is low, the battery temperature tends to drop below the rechargeable temperature therefore it is likely that battery cannot be charged.

4.3.3 Estimation of carbon dioxide reduction

To estimate the carbon dioxide reduction, we referred to the scheme approved by the Domestic Credit Certification Committee, and calculated the amount of carbon dioxide emission reduced by adopting E-Bus as an alternative to diesel bus. Figure 9 shows the result of our estimation of carbon dioxide reduction.

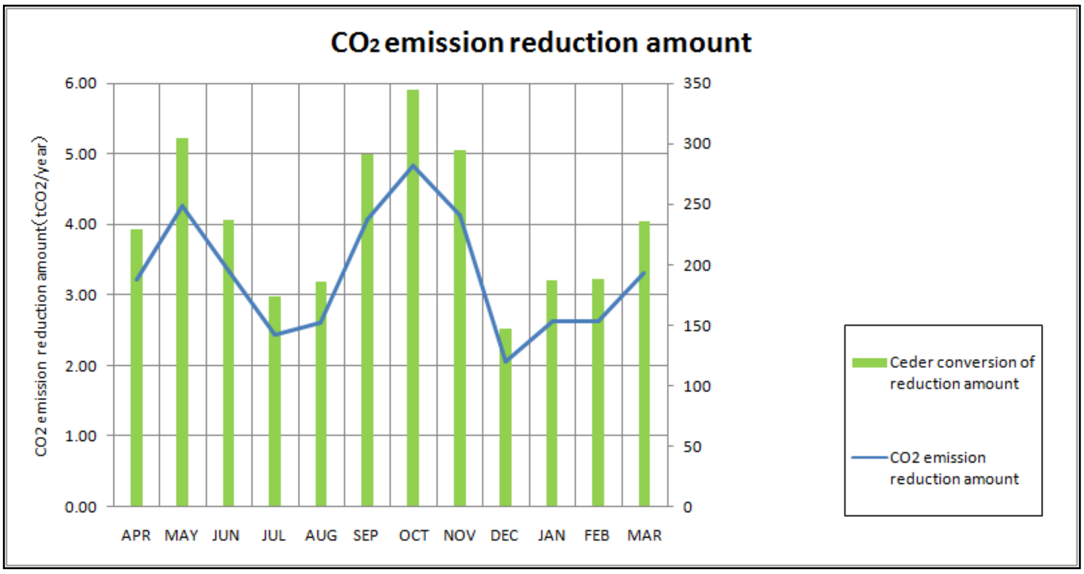

Figure 9: Amount of carbon dioxide reduction

As compared to the operation of diesel bus, the amount of average yearly carbon dioxide reduction from the commencement of operation was 3.3t CO2/year. This confirms that the introduction of e-BRT definitely works for environmental load reduction.

References

[1] JREA volume 57（Published in Sep, 2014）: Summary of Electric Bus introduced to Kesennuma BRT (e-BRT)

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