International Conference on Applied Energy 2019
Aug 12-15, 2019, Västerås, Sweden
Paper ID: 261

Relocated Transport Carbon Emission After Electric Vehicle Promotion in Tokyo, Japan-Analysis Based on Big Data and Supply Chain

Zhang Qiong[1], Long Yin [1*], Zhang Haoran[2]

1 Department of Environment Systems, Graduate School of Frontier Sciences, The University of Tokyo, 5-1-5 Kashiwanoha, Kashiwa, Chiba 277-8563, Japan

2 Center for Spatial Information Science, The University of Tokyo, 5-1-5 Kashiwanoha, Kashiwa-shi, Chiba 277-8568, Japan

ABSTRACT

Petroleum contributes to more than 90% of the total energy consumption mix in the transport system, and transport emission releases approximately 14% of total greenhouse gas emission. To achieve emission reduction target of the transport sector, vehicle electrification is widely discussed under the concept of the next-generation transportation system. In this study, we select Tokyo city as case study and collect personal travel data across the year of 2011. Travel model is classified by walk, bicycle, train and vehicle by Big Data. After capturing gasoline consumption distribution, this study further discusses the carbon emission distribution by city-scale input-output data. Findings firstly indicate the transport emission distribution has largely relocated after the vehicle electrification. The result also shows although the indirect emission after electrification has increased 1.167 times than before, the total emission has decreased by 73% and has a considerable reduction potentiality in the future.

Keywords: Transport emission, Vehicle electrification, Personal travel mode, Indirect emission, Input-output analysis.

1. INTRODUCTION

Substantial growth in road transport is expected to increase markedly shortly, which is to meet the need for increasing interregional/national connections under urbanization and globalization. According to a study commissioned by the World Business Council for Sustainable Development, light-duty vehicle ownership could increase from roughly 700 million to 2 billion over the period 2000-2050（Hawkins et al.2013). Here, petroleum contributes to more than 90% of the total energy consumption mix in transport system, and transport emission release more approximately 14% of total GHG (Greenhouse Gas) worldwide which account for almost 20% of the total primary energy use (Abdul-Manan 2015). Therefore, efficient and greener transportation systems are preferable for achieving emission reduction target as well as foster a stable and sustainable energy supply environment. As an alternative vehicle technology, EVs (Electric vehicles) are considered to be the most promising one to replace internal combustion engine vehicles (ICEVs), which majorly relies on crude oil product.

However, EVs have not been widely used so far, and the market for passengers became available from 2012(Greaves et al. 2014). EVs have a higher initial price and facing varied questions in meeting mobile requirements compared with ICEVs, such as frequently recharging, long charging times, and the ignorance of up-stream power generation's emission. Therefore, EVs, as potential long-term solutions for sustainable personal mobility, are more complex than ICEVs when assessing their real ability to reduce carbon emissions (Hongrui Ma et al.2012). Under this circumstance, a comprehensive comparison of the carbon emissions of EVs and ICEVs is a necessary condition to support policy making, rational research and investment decisions.

To capture the gasoline consumption without transport electrification, gasoline consumption data is essential to adequately describe the direct emission releasing. Recent studies emphasize the potential of Big Data to explore public transport users' behaviors, to simulate individual mobility choices in carpooling and to classify activity patterns, with applications in the fields of mobility networks design and infrastructures and multimodal transportation systems (Gennaro 2016). Here, we propose a framework based on mobile phone

Selection and peer-review under responsibility of the scientific committee of the 11th Int. Conf. on Applied Energy (ICAE2019).

GPS data to evaluate road gasoline consumption by ICEVs and future power consumption by EVs. Based on the urban road structure, the map matching method is carried out to modify the measuring error in vehicle trajectories. Then, using the trajectories and weather data as the input, the road gasoline consumption and power consumption in each urban grid are evaluated by vehicle energy consumption model. At last, the supply chain information generated by Tokyo input-output table will show the relocation of carbon emission after the vehicle electrification from the insight of the energy supply chain.

As mentioned, the relocation of emission by energy source change leads to reconsideration on emission leakage issue. Carbon leakage is unavoidable according to the industrialization and globalization. Such as globalization has led to increasing geospatial separation of production and consumption (Wiedmann and Lenzen 2018). Given this situation, this study aims at evaluating the emission variation and relocation before and after the vehicle electrification. The result will give us a clear comparison of EV's reduction potentiality by considering the entire supply chain of energy.

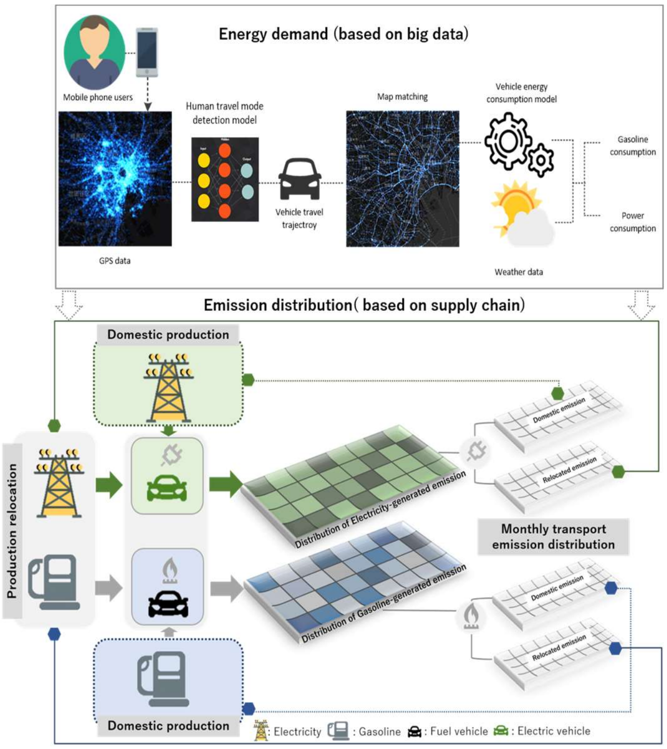

Fig. 1 Framework of transport energy and emission evaluation in study area

2. METHODOLOGY

2.1 Transport energy evaluation based on personal travel data

Figure 1 shows the flowchart of this study. In order to reveal the emission gap generated by different vehicle energy consumption, we propose a framework basing on mobile phone GPS data to evaluate road gasoline consumption and future power consumption by EV. First, a preprocessing is implemented to normalize the raw GPS data. Then, by using the travel mode detection model, the vehicle trajectories are picked up from the GPS dataset. Based on the urban road structure, the map matching method is carried out to modify the measuring error in vehicle trajectories. Finally, using the trajectories and weather data as the input, the road gasoline consumption and power consumption in each urban grid are evaluated by vehicle energy consumption model1. In order to apply our model to real-world human activity, we utilize GPS trajectories obtained in Tokyo city throughout 2011. "Konzatsu-Tokei (R)" Data refers to people flows data collected by individual location data sent from mobile phone under users' consent, through Applications provided by NTT DOCOMO, INC. Those data is processed collectively and statistically in order to conceal the private information. Original location data is GPS data (latitude, longitude) sent in about every minimum period of 5 minutes and does not include the information to specify individual.

※ Some applications such as "docomo map navi" service (map navi・local guide).

In this study, we take the city of Tokyo as case study to capture its road gasoline consumption and then give out the emission responsibility change after EVs promotion.

2.2 Travel Mode Detection.

Based on the GPS personal travel data of Tokyo, a stay segment within a trajectory corresponds to a group of consecutive points representing a user who is stopped at a location. In this study, stay segments were extracted based on thresholds for distance and time. Neighboring points with distances and times lower than the threshold were classified as stay points. In addition to the conventional stay points, some noise points were also featured in the GPS trajectories; those points had a large offset from the true location. Note that it was possible for the distance from the noise points to the neighboring points to be larger than the threshold as if they corresponded to a stay status. To detect these outliers, a Gaussian distribution was utilized to represent the GPS points, with the mean ▯ and standard deviation has been calculated.

2.3 Vehicle Energy Consumption Model

For the vehicle performance of our model, we estimate the traction energy requirement and the internal efficiency of a given speed curve. The former uses the EPA test dynamometer coefficient and the latter uses the CAFE test results (Zhang et al.2018, Zhang et al. 2019). The Nissan leaf is taken as the studied sample of battery electric vehicle. The Ford Focus is taken as an example of an ICEV.

The model of energy flows for a battery electric vehicle is shown as follows:

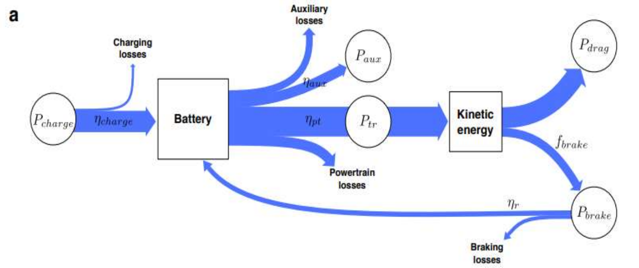

Figure 2: Model of energy flows for a battery electric vehicle

Where P_{charge} is the charging power, P_{aux} is the auxiliary power, P_{tr} is the tractive power, P_{drag} is the drag power, and P_{brake} is the brake power. η represents the corresponding efficiency.

Auxiliary power devoted to climate control is assumed to be a function of external temperature. We use a simplified steady state heat balance model,

$P_{aux} = k|T_{outside} - T_{inside}|/COP$

Where, where k is the thermal conductivity of the vehicle, which we take to be 350 W/C°, and the internal temperature is set as a function of the outside temperature. COP is an effectively infinite value.

2.4 Summation of segment value into meshes

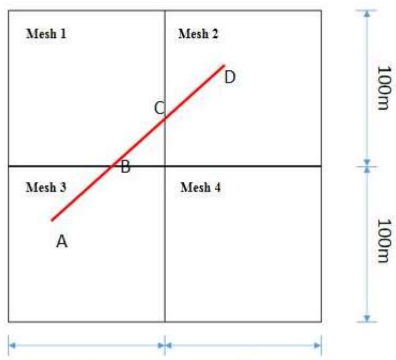

Figure 3: segment value into meshes

Since the latitude and longitude coordinates can give the trajectory, the obtained emission trajectory follows the linear sequence structure. In order to analysis the road emission distribution in the city, we need to transform the emission trajectory into the mesh structure. Here, we take a trajectory (A-B-C-D) as an example. The trajectory passes tree meshes (meshes 3- meshes 1- meshes 2). We assume that the obtained emission values of the tree trajectory segments are ev_{AB}, ev_{BC}, and ev_{CD} respectively. Then, the summation value of Mesh 1 contributed by the trajectory (A-B-C-D) equals to ev_{BC}. Same as the ev_{CD} for Mesh 2 and the ev_{AB} for Mesh 3.

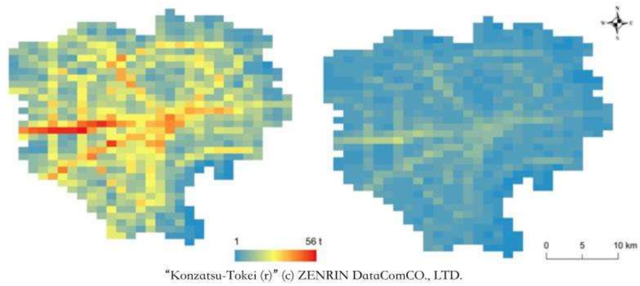

Figure 4 Relocated emission before (left) and after (right) vehicle electrification in Tokyo

2.5 Gasoline and electricity consumption of travel model

To the transport emission, a large amount of that is expected to be released during the upstream process. Especially after the promoting of electric vehicles, almost all the emissions are generated by power generation, which complicates the current emission allocation issue much more than before. If the transport system is supported by gasoline, the majority of emission is generated in energy combustion process. Therefore, a comprehensive emission allocation is in demand to reallocate the emission responsibility after the vehicle electrification. To address this problem in study area, we applied energy extensities generated by a city-level input-output table (Long and Yoshida 2018). The energy consumption evaluation is then can be calculated into corresponding emission volume and future be further divided by geographical boundaries as well as emission types. Such as gasoline consumption can be divided into direct emission by direct combustion when users are driving, also the emission by the up-stream emission of oil-product production can also be estimated as the indirect emission. After the vehicle electrification, a large part of transport emission is transferred to the power generation phase. Although there is no emission is the final using stage, emission resulting from electricity generation should be considered as indirect emission and embodied in driving behavior. As the driving occurred, the emission responsibility should be attributed to the corresponding driving behavior, no matter what kind of energy they used in the final stage.

3. RESULT

According to personal travel data mining, this study firstly derived mesh-based gasoline consumption based on each travel mode. The relocated emission distribution is estimated by the energy demand transferred from gasoline to electricity (Figure 4). As the estimation result is shown in Table 1, under the gasoline-support transportation system, the majority (87.58%) of carbon emission is released directly within Tokyo city, while the indirect emission is found to be 8.38% domestically and 4.04% outside. After the vehicle electrification, transport emission is majorly released outside of Tokyo city with a ratio of up to 86.45%. The result shows although the indirect emission after electrification has increase 1.167 times than before, however, the total emission has decreased 73% after the vehicle electrification.

Table 1: Ratio detail of emission source of relocated emission

Gasoline			Electricity	
Direct	Indirect		Domestic	Other areas
	Domestic	Other areas		
87.58%	8.38%	4.04%	13.55%	86.45%

4. CONCLUSION

The recent debate remains on the issue of emission transfer by either direct or indirect ways. To the transport sector, emission relocation is a critical social issue to the promotion of next-generation vehicle since the energy demand will be transfer from gasoline to electricity. Therefore, quantification of relocated carbon emission from a life cycle perspective is necessary. In this study, we proposed a combined methodology with personal travel data mining and supply chain analysis. The travel mode analysis enables the mesh-based petroleum consumption distribution. The input-output model is applied to calculate the emission volume released indirectly and outside of Tokyo city. The result shows the indirect emission varies a lot before and after the vehicle electrification in Tokyo city, which indicate the future EVs promotion will cause the regional carbon leakage issue. However, the overall emission of EVs promotion still has a considerable potentiality to reduce the non-point emission releasement, which is expected to contribute to transport emission reduction to a larger extent.

ACKNOWLEDGMENT

This work is supported by the Grant-in-Aid for Early-Career Scientists (19K15260) from the Japan Ministry of Education, Culture, Sports, Science and Technology.

MAJOR REFERENCE

1. Abdul-Manan, A. F. N. 2015. Uncertainty and differences in GHG emissions between electric and conventional gasoline vehicles with implications for transport policy making. Energy Policy 87:1-7.
2. Needell, Z. A., J. McNerney, M. T. Chang, and J. E. Trancik. 2016. Potential for widespread electrification of personal vehicle travel in the United States. Nature Energy 1:16112.
3. Wiedmann, T., and M. Lenzen. 2018. Environmental and social footprints of international trade. Nature Geoscience 11:314-321.
4. Zhang, H., Song, X., Long, Y., Xia, T., Fang, K., Zheng, J., ... & Liang, Y. (2019). Mobile phone GPS data in urban bicycle-sharing: Layout optimization and emissions reduction analysis. Applied Energy, 242, 138-147.
5. Zhang, H., Song, X., Xia, T., Yuan, M., Fan, Z., Shibasaki, R., & Liang, Y. (2018). Battery electric vehicles in Japan: Human mobile behavior based adoption potential analysis and policy target response. Applied energy, 220, 527-535.
6. Long, Y., & Yoshida, Y. (2018). Quantifying city-scale emission responsibility based on input-output analysis–Insight from Tokyo, Japan. Applied energy, 218, 349-360.
7. Hongrui Ma et al.2012 A new comparison between the life cycle greenhouse gas emissions ofbattery electric vehicles and internal combustion vehicles
8. Michele De Gennaro et al.2016 Big Data for Supporting Low-Carbon Road Transport Policies in Europe: Applications, Challenges and Opportunities. Big Data Research