Possibility to Realize Low Carbon City in Middle-sized City of Asia -Case Study in Khon Kaen City, Thailand-

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1. Introduction

In recent years, the idea of a Low Carbon Society is discussed as the one of the solution for a global warming problem. The automobiles have been being spread rapidly through many cities of Asia. However, middle-size cities have controllable spaces for urban development and possibility of improving public transport. Thus, it is important to carry out comprehensive policy which includes land use and low carbon public transportation in the early stages of development.

Therefore, this study focuses on Khon Kaen city, Thailand which has plan of BRT introduction from existing public transport (Songthaew). The purpose of this study is to discover effects of introducing comprehensive policy by estimation of CO_2 reduction to consider introduction of BRT and TOD, conversion from gasoline vehicles to Electric Vehicles, Hybrid Vehicles and Ethanol Buses.

2. Literature Reviews

He et al. (2007) compared the CO_2 emission reductions to apply TOD policies or AOD (Automated Oriented Development) in Dongguan city, China. In the study, they assumed several scenarios in which ether land use policies is set to allocate high density residence around five hundred kilometer from station of public transit. The CO_2 emission and energy consumption under the both scenario were estimated.

Gojash(2007) estimated the maximum possible trips subjecting to emission constant in case of Chengdu, China. These results are depending on road network and public transit in each targeted study area. Therefore, the estimated value cannot be compared over different cities. Introducing as one of the representative studies, Gojash estimated the increase of 2% possible trips under the introduction of one subway line in Chengdu, China.

In this study, we focus on the effect of CO_2 reduction under the combination of several policies such as TOD policy, public transit policy, technological innovation and freight traffic. This study would provide some important outcomes for the middle-sized cities of Asia counties.

3. Methodology

The methodology consists of three steps: scenario setting, demand forecasting model and estimating CO_2 emission. The scenario is set to consider the potential strategies which would contribute for reduction of CO_2 emission. For verifying the impact of introducing BRT in Khon Kaen, the combined model with traffic assignment and modal split on traffic demand forecasting model is employed. Based on a result of traffic assignment, CO_2 emission is estimated by using the CO_2 emission factor developed by several institutions for considering current traffic situation in Thailand.

The future OD matrix in 2030 on Business As Usual(BAU) is estimated based on the published data about population and its density in Khon Kaen city. The estimation on all scenarios used the future OD matrix on BAU. The OD matrix under introduction of TOD is calculated in assumption of generated trip converted from all zones to the zones along BRT. The Scenario A, B and C means the ratio of generated trip 10%, 30% and 50% respectively for reproducing the situation of movement of people to along BRT lines.

It is assumed that all BRT lines are constructed in 2030. In the case with BRT, the existing Songthaew routes are discontinued and all passengers of Songthaew are assumed to be shifted to BRT. Technological innovation for engine type of vehicle would be occurred and EV/HV would be used more in near future. Therefore the conversation rate to EV/HV from each mode is considered: 0%, 30% and 50%. Based on trend of EV/HV in Thailand, Truck and motorcycle would convert to EV and passenger car would convert to HV. The conversion rate is set with reference of the advanced vehicle strategies 2010, Ministry of Economy, Trade and Industry of Japan.

Scenario 1 was assumed the Songthaew is main public transportation without the introduction of BRT and shifting from passenger cars, motorcycles and freight vehicles to electric freight vehicles, hybrid vehicles. Scenario 2 is only introduction of BRT. Scenario 3 is with introduction of BRT and shifting from passenger cars, motorcycles to electric vehicles, hybrid vehicles. Scenario 4 is with introduction of BRT and shifting from freight vehicles to electric freight vehicles. Scenario 5 is with introduction of BRT and shifting from shifting from passenger cars and freight vehicles to electric freight vehicles and hybrid vehicles. Scenario 6 is with introduction of BRT and shifting from passenger cars, motorcycles and freight vehicles to electric freight vehicles, hybrid vehicles.

Keywords: TOD, BRT, CO_2 Emissions, Low Carbon Society, Diffusion of EV and HV

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The combined modal split and assignment model is employed to consider BRT introduction. In this study, the JICA STRADA that is one of software for transport demand forecasting, making OD matrix and the road network was utilized. The combined model is solved by satisfying the requirements of network equilibrium expressed by the following mathematical optimization problem.

$$\begin{aligned}\min .Z(x(f),q,O) &= \sum_m \sum_a \int_0^{x_a^m} t_a^m(\omega)d\omega \\ &+ \sum_{rs}\sum_m\sum_p\sum_k \frac{1}{\theta_1^p} f_{m,k}^{rs,p} \ln\left(f_{m,k}^{rs,p} / q_m^{rs,p}\right) \\ &+ \sum_{rs}\sum_m\sum_p \frac{1}{\theta_2^p} q_m^{rs,p} \ln\left(q_m^{rs,p} / q^{rs,p}\right) \\ &+ \sum_{rs}\sum_m\sum_p q_m^{rs,p} C_m^{rs,p}\end{aligned} \quad (1)$$

Where, $f_{m,k}^{rs,p}$: traffic volume of purpose p and mode m on route k for OD pare between zone r and s, $q_m^{rs,p}$:OD trip of purpose p and mode m for OD pare between zone r and s, $q^{rs,p}$: OD trip of purpose p for OD pare between zone r and s, $C_m^{rs,p}$: travel cost of purpose p and mode m for OD pare between zone r and s

The equation to calculate CO_2 emission is formulated as follow:

$$E = \sum_{m\in M}\sum_{r\in R}\sum_{s\in S} q_{rs}^m l_{rs}^m EF_{rs}^m \quad (2)$$

$$EF_{rs}^m = \left(a^m V_{rs,m}^2 + b^m V_{rs,m} + c^m\right) \quad (3)$$

Where, $m \in M$:m is the set M of available mode between OD pair between zone r and s, $r \in R$:r is the element of the set R of origin zone, $s \in S$:s is the element of the set S of destination, q_{rs}^m:trip distribution by mode between zone r and s, l_{rs}^m:the shortest distance by mode m and between zone r and s, EF_{rs}^m:emission factor of CO_2 by vehicle type, $V_{rs,m}$:average speed by vehicle type between zone r and s, a^m, b^m, c^m : parameters of emission factor by vehicle type

4. Results

As the result, the figure 1 shows the CO_2 emissions in all scenarios. It was indicated that the C-6 scenario which is strongest scenario of introducing TOD and BRT with shifting to electric freight vehicles, hybrid vehicles reaches the highest reduction rate (48.2% in comparison with BAU) of CO_2 emissions among all scenarios.

In comparison with the scenario 1 and 6 over A, B and C, the effect of introducing BRT is about 10%. And then if TOD policy was introduced, CO_2 was reduced about 10% in scenario A, about 20% in scenario B and about 30% in scenario C.

Regarding the technological innovation as mentioned the conversion rate from gasoline vehicle to EV and HV, the effect of converting freight truck to EV is about 5% as showing the scenario 1 and scenario 4. Scenario 5 adding the conversion of passenger car to HV on the scenario 4 has the effect about 5% over scenario A, B and C. Finally, if motorcycle is converted to EV from gasoline engine, a few reduction rates was shown about 1 or 2 % in comparison with the scenario 5.

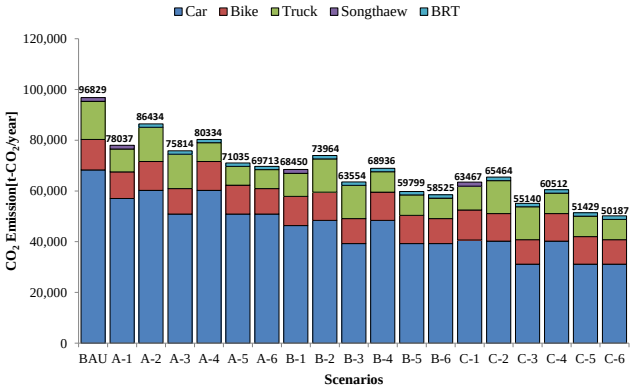

Figure 1 CO_2 emissions of all scenarios

5. Conclusion

In this study, it was indicated that the scenario introduced TOD and BRT with shifting to electric freight vehicles, hybrid vehicles could be reduced the CO_2 emissions by up to 48.2% as compared with BAU scenario. In addition, the CO_2 reduction effect was basically ineffective if only TOD policy, BRT or shifting to electric vehicle was introduced in Khon Kaen city. Thus, we concluded that it is necessary to introduce the comprehensive land use and transportation policy in the future for realizing low carbon city.

In addition, Khon Kaen citiy is typical type of middle-sized city of developing country. Therefore, there is possibility toward low carbon society in other middle size cities.

Further studies are needed to estimate the CO_2 emissions in the case developed terminal traffic along BRT lines and reallocated logistic facilities, and construct a modal choice model for increasing accuracy of future modal share.

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