STUDY ON THE ESTIMATION OF CO2 EMISSION REDUCTION FOR LONG TIME WHEN THE URBAN AREA CHANGED: CASE STUDY IN KHON KAEN, THAILAND

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1. INTRODUCTION

In terms of measures against global warming, huge amount of CO2 emission reduction from urban transportation has been absolutely imperative because automobile usage is expected to grow in many developing nations. To realize such huge reduction, many studies proposed comprehensive countermeasures including introduction of urban rail or guide way system, introduction of renewable energy, usage of eco-friendly vehicle and introduction of taxation and economical restriction such as road pricing and estimated CO2 emission reduction by implementing such countermeasures through change of travel behavior of households and enterprises and also change of automobile usage. However, change of urban structure such as Transit Oriented Development (TOD) has not be regarded on those estimation which might bring huge reduction of CO2 emission. Also, most of studies estimated CO2 emission reduction in certain targeted year only. Thus dynamical impacts of countermeasures on CO2 emission is not clarified. Therefore, in this study, relationship between urban area and Vehicle Kilometer Traveled (VKT) was analyzed based on former study in Khon Kaen, Thailand first. Then, a system dynamics model was developed to estimate CO2 emission based on relationship between urban structure and VKT as well as other economic and technological measures. Final, impacts of proposed measures were analyzed.

2. LITERATURE REVIEWS

To understand sustainable growth of a city from the view point of better air quality and low carbon, many system dynamics models which are mainly estimate energy demand, air pollution and CO2 emission in an urban area have been developed. Chen, et al. (2006) estimated NOx emission by vehicle type in Taipei City from 1969 to 2005 using system dynamics model based on population and economic growth. Wang, et al. (2008) also developed urban transportation model in Dalian City, China and tested impacts of 5 policies on NOx emission. Duran-Encalada, et al. (2009) developed PROPOLIS model to discuss sustainable development in Puerto Aura, Mexico which allows to discuss policies in many sectors. Beside those studies, relationships between CO2 emission and transportation activities in national or inter-regional level have been modeled based on system dynamics concept and policies regarding CO2 mitigation were examined in long term. Stefano, et al. (2010) developed the energy model to find out sustainable transport system. Han, et al. (2008) developed system dynamics model for inter-city passenger transport in China and estimated energy consumption and CO2 emission with three scenarios. Stepp, et al. (2009) discussed the role of the feedback effect of GHG mitigation policy on transport sector conceptually. Egilmez, et al. (2012) estimated CO2 emission from highway in US with several scenarios as well. Although there have been several studies evaluated the effect of CO2 emission reduction by implementing transportation policies. However, comprehensive policies in which several policies are combined with various aspects considering hierarchy and complexity have never been evaluated under the integrated methodology, although individual policy has been dealt with the different methodologies in those studies.

3. METHODOLOGY

3.1 Causal Loop Diagram

Causal loop diagram is determined the relationships of cause and effect. In this study, the proposed causal loop diagram is shown Fig. 1. This diagram was constructed based on some existing studies which were certified as sensitive models. Also, this diagram was taken into account regardless of the relationships between population, GRDP, total number of vehicles, urban area, VKT, and CO2 emission. Especially, CO2 emissions were calculated from fuel consumption and VKT. In addition, an incremental VKT occurs as a result of the change of urban area and increased number of vehicles respectively. On the other hand, the growth of population and GRDP has played a significant role in generating an effect on increasing urban area, VKT and number of vehicles. In addition, fuel price, average fuel economy, and CO2 emission factors changed associating with technical innovation are constructed in this diagram. These variables are very important to implement the Low Carbon policies.

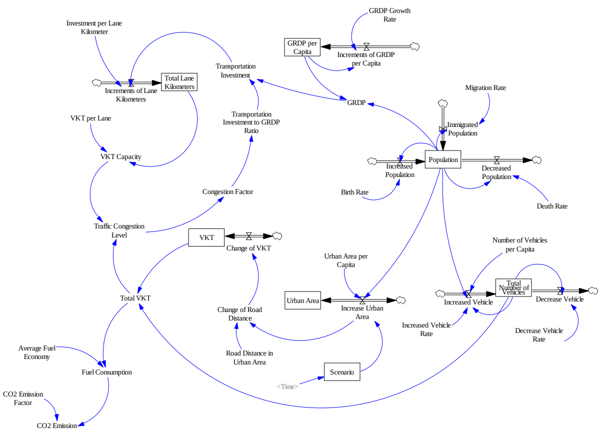

Fig. 1 Causal Loop Diagram of the Proposed Model

Keywords: Khon Kaen, System Dynamics, CO2 Emission, Urban Area, VKT
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In this study, it is estimated the impact of CO2 emission due to change of the urban area by using this diagram. Also, this study uses the base years of 1998 and 2030 is set as the target year.

3.2 Scenario Design

In this study, 3 scenarios were set to examine the conventions of selected policies, namely, Business As Usual (BAU) scenario, Middle Density scenario, High Density scenario. These scenarios are supposed that reproducing the situation of immigration of the people from suburban to central of downtown. Concentrated population to the central of downtown leads to reduction of CO2 emission because of total VKT are decreased. Also, main purpose of introducing these scenarios is impact of the CO2 emission depending on the change of urban area. On the other hand, regarding BAU scenario, the immigrated ratio is 0 % between 1998 and 2030. So, urban area is not changed. Middle Density scenario is assumed to decrease the urban area. In 2030, urban area attains 50% of present area. In turn, Middle Density scenario and High Density scenario are assumed to ratchet down urban area to 50% and 30%.

4. RESULTS

As a result, shown in Fig. 2, this figure is indicated the accumulated VKT of 3 scenarios. Values of accumulated VKT were BAU scenario: 2,358,000 [km], Middle Density scenario: 1,470,000 [km], and High Density scenario: 1,724,000 [km]. BAU scenario was about one and half times as value as High Density scenario because of accumulated VKT were had a huge effect on urban area. Also, Middle Density scenario was effective against accumulated VKT.
On the other hand, shown in Fig. 3 is indicated the CO2 emission of 3 scenarios. Values of CO2 emission were BAU scenario: 2011 [million kg-CO2], Middle Density scenario: 1451 [million kg-CO2], and High Density scenario: 1244 [million kg-CO2]. CO2 emission of BAU scenario also was higher among the other scenarios. The reason like this result was related to VKT because of CO2 emission is so high as to change of slope is big.

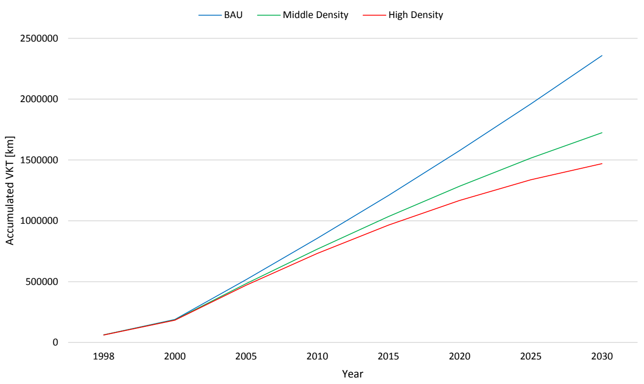

Fig. 2 Accumulated VKT of 3 Scenarios

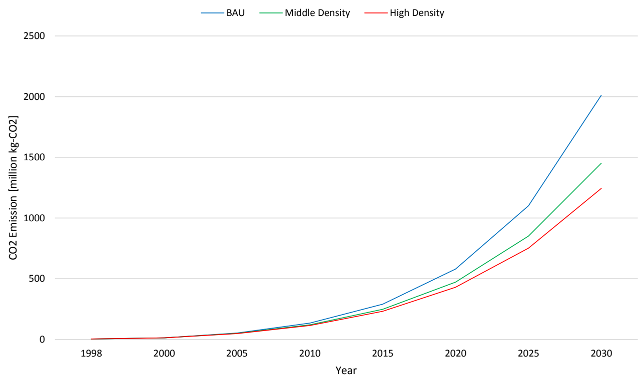

Fig. 3 CO2 Emission of 3 Scenarios

5. CONCLUSIONS

In this study, we could estimate the CO2 emission reduction with the change of urban structure in Khon Kaen as a case of a developing country. It was found that the scenario implementing density growth of urban area could reduce 38.1% of CO2 emissions, as compared with BAU scenario. However, CO2 emission reduction was rather small if only single policy was applied in Khon Kaen. For further study, we need to estimate CO2 emission when it is implemented the comprehensive polices in which land use plan, rail or guide way transport, technical innovation, and energy consumption are included to realize a Low Carbon Society.

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