Evaluation of Potential Urban Transport and Land Use Measures to Reduce Greenhouse Gases (GHGs) Emission

Pongrid KLUNGBOONKRONG[a], Sittha JAENSIRISAK[b],Phongphan TANKASEM[c], Jaruwit PRABNASAK[d]
[a, c] *Sustainable Infrastructure Research and Development Center (SIRDC), Department of Civil Engineering, Faculty of Engineering, Khon Kaen University, Thailand*
[b] *Civil Engineering Department, UbonRatchathani University, UbonRatchathani, 34190, Thailand*
[d] *King Mongkut's Institute of Technology Ladkrabang, Bangkok , Thailand*
[a] *E-mail: kku.sirdc.17@gmail.com*
[b] *E-mail: sittha.j@gmail.com*
[c] *E-mail: civil_ter@hotmail.com*
[d] *E-mail: kpjaruwi@kmitl.ac.th*

Abstract: Transport sector have been well recognized as the key contributor to the Greenhouse Gas (GHG) emission and the main generator of global warming and climate change (Dulal et al, 2011). Motorized car is the second largest contributor (behind the trucks) of GHG emission (Chapman, 2007).This paper presented the analysis and evaluation of implementing transport and land use measures in reducing GHG emissions generated from the transport sector in the road network of the Khon Kaen University, Khon Kaen, Thailand. This research adopted the Bottom-Up 2 approach to estimate the baseline (*without project*) GHG emissions as well as the (with project) GHG emissions for different scenarios by using CDM2, MLIT and PCD methods in the year 2011, 2021 and 2031.The cleaner technology strategy clearly showed the highest performance of the GHG emission reduction, followed by land use planning strategy and restriction of private vehicle usage, respectively. The public transit improvement strategy illustrated the lowest. The performance of the combined scenarios also consistently reflected the potential performance capacity of each individual scenario in each combine done.

Keywords: Climate change, Greenhouse Gas (GHG) emission, Transport and land Use Measures, Bottom Up 2 Approach

1. INTRODUCTION

As the population, social and economic growth as well as the land use development in urban areas rapidly rises, travel demand will also be increased. Consequently, the increment of individual incomes, private car-ownership and car usage has been the driving force to the private vehicle dependency. In addition, economic and land use development can potentially stimulate urbanization and sub-urbanization (Hayashi, 1996). Unfortunately, traffic congestion, road accidents, adverse environmental effects, global warming and climate change has been most pronounced and explicitly realized.

Transport related activities have been widely recognized as the principal contributor to the Greenhouse Gas (GHG) emission and the main generator of global warming and climate change. Experts pointed out that the level of the recent Carbon dioxide (CO_2) concentration in the atmosphere has been considerably greater than the normal natural ranges and this concentration will be estimated to be double by the end of this century (Dulal et al, 2011). Motorized car is the second largest generator (after the trucks) of GHG emission in the transport sector (Chapman, 2007).

The mitigating measures (eg planning, regulatory, economic, information and technology instruments) to atmospheric problem of the GHG emission reduction were recently discussed and assessed (GTZ, 2007; Chapman, 2007; Hensher, 2008; Banister, 2011; Dulal et al, 2011).The systematic approach will be adopted to investigate and quantify the potential GHG emission reduction of the implementation of those individual and/or combined measures. The amount of the GHG emissions reduction between in the "*Without Project*" and "*With Project*" scenarios will be accurately estimated and evaluated. This task will be the critical and vital in assessing and selecting the most appropriate mitigating instrumental measures. The main objectives of this paper are as follows: (i) to conduct the baseline study of Greenhouse Gas (GHG) emissions generated from transport sector in the study area and (ii) to analyze and evaluate the impact of implementing different potential measures in reducing GHG emission generated from the transport sector in the study area.

2. CURRENT CONDITIONS OF THE STUDY AREA

Khon Kaen University (KKU) is located in the northwestern part of Khon Kaen city situating in the middle of the northeastern region of Thailand, approximately 450 km. apart from Bangkok. KKU was selected as study area and the total area of KKU covers approximately 900 hectares as shown in Figure 1and has more than 50,000 residents including academia, students, supporting staff members and others.

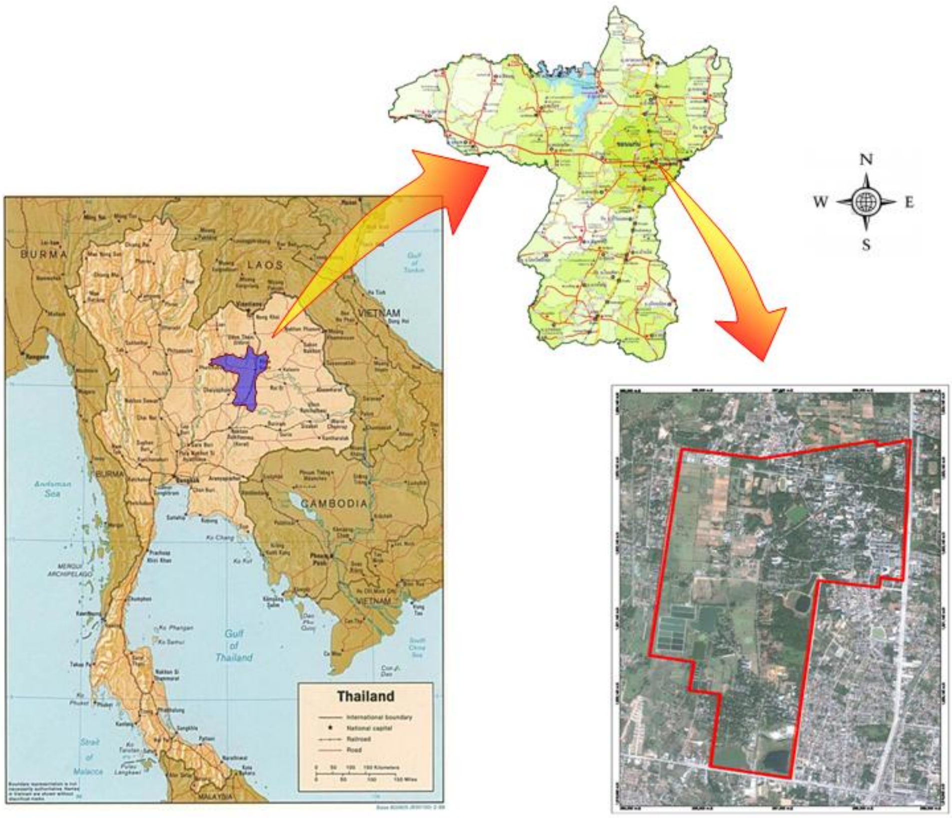


Figure 1. Location of Khon Kaen University (adapted from TGO (2012))

Land use purposes were divided into three categories including (i) land use for academic purpose, (ii) land use for agriculture and livestock and (iii) land use for natural and green space. Its primary location together with the development of the university and the Srinagarindra Central Hospital, the largest medical hub of the Indochinese countries, has rapidly accelerated the land use changes in the vicinity of the KKU. There are several communities surrounded the university. The fast growth of these communities has influenced the alteration of activities system in the surrounding areas. Mid-rise apartments, shops, restaurants, food stalls, and other related activities have taken place to serve high demand from KKU residents and others. The study area has become one of the most active urban areas of the Khon Kaen city.

KKU campus, though is an academic area, it is comparable to a small town with various uses of land and buildings. The pattern of movement within the campus therefore corresponds to the pattern of activity system. Road network system within KKU campus mostly are minor roads and collector streets associated with moderate road traffic or local routes with low speed design, frequent access points and access to buildings. However, since the northwest side of Khon Kaen City is considered a large enclosed area, KKU campus eventually has become the main access for local residents to connect with other parts of the city. Local residents both within and outside the area have used main roads in KKU campus as a shortcut to Mitrapharp Road (AH12) and Maliwan Road (AH16) resulted in experiencing heavy through traffic volume on the main streets and collector roads in the campus.

Road network as illustrated in Figure 2 and traffic management systems in the study area were constructed and implemented covering the entire area. The existing traffic management systems were diversified ranging from Local Area Traffic Management (LATM) (including roundabout, speed humps, and others) to Sub-arterial Road Traffic Management (SATM) (including sharing the main street and others) and Arterial Traffic Management (ATM) (including traffic signals, parking control, one-way road and others) as presented in Figure 3 Three public transport systems provided their services in KKU have been "*Song – Thaew*" seated buses (para-transit system), air-conditioned vans, and the shuttle bus service.

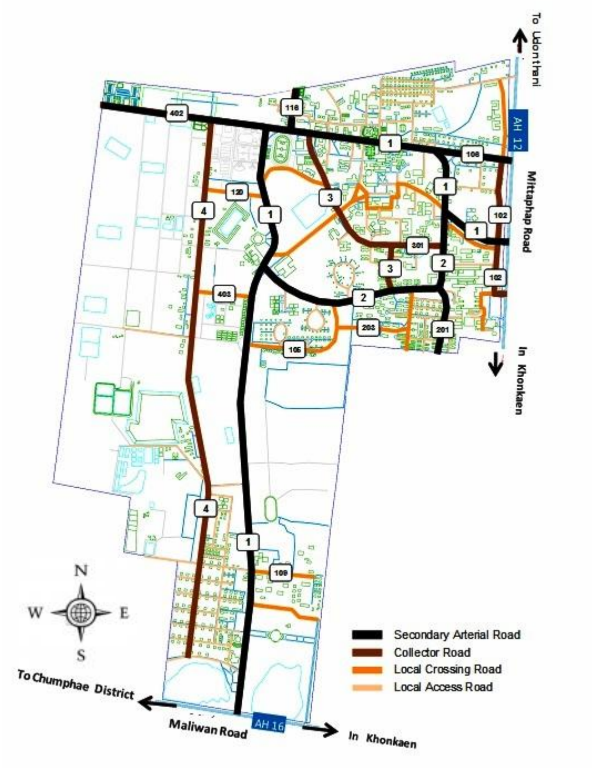


Figure 2. Road network in the study area (TGO, 2012)

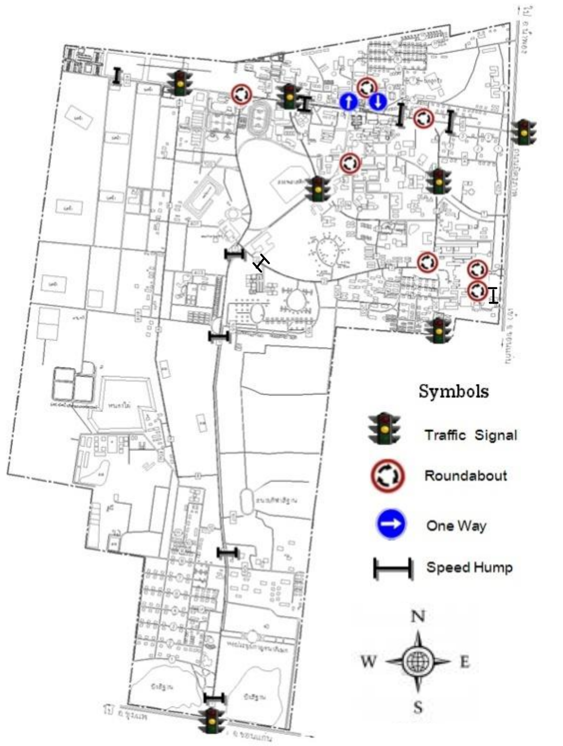


Figure 3. The existing traffic management systems in the study area(TGO, 2012)

Based on the recently completed KKU master plan study, a number of future construction plans in KKU setting as high priority include the construction of multi-purposes gymnasium buildings; the special physical and land use plan of the faculty of engineering; the design of buildings and landscaping in the new academic zone, the KKU medical hub and health science center plan and others.

3. TRAFFIC AND TRANSPORT DATA COLLECTION

In order to understand existing conditions and issues of traffic and transport system in the study area and to prepare appropriate future plans, the traffic and transport conditions in the study area were surveyed by using various standard data collecting methods. The traffic data collected from the field surveys could be divided into six categories including mid-block and intersection traffic volumes, average delays and queue lengths at intersections, average operating speed, and several physical characteristics of road network. In each specific surveyed day, the traffic data collection was conducted in three different time periods: (i) morning peak hour period (07:00–10:00); (ii) off-peak hour period (11:00–14:00) and (iii) afternoon peak hour period (15:00– 18:00). Some examples resulted from these traffic data collections and surveys are presented in Figure 4, 5 and 6 below.

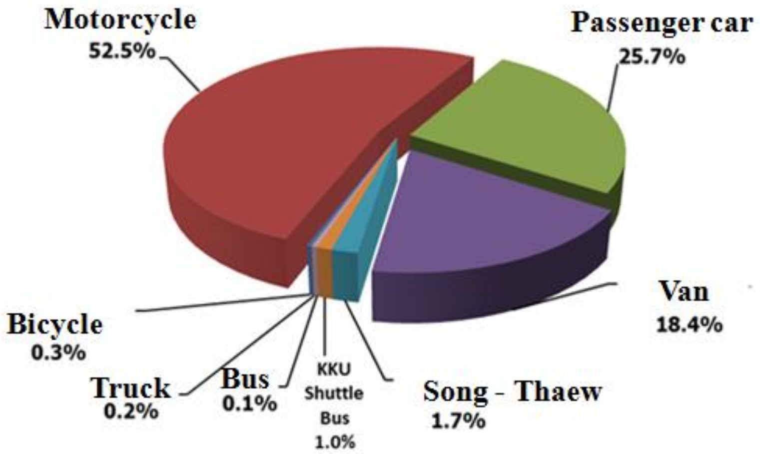


Figure 4. Vehicle composition of traffic streams in KKK road network
(TGO, 2012)

4. URBAN TRANSPORT PLANNING DEVELOPMENT

There are three main steps in analyzing the proposed traffic and transport plans, including (i) transport surveys and data collection, (ii) urban transport model development and (iii) analyzing and forecasting transport demand by employing sequential 4-step urban transport model. The selected future years to be predicted and analyzed are 2011, 2021 and 2031.

As for trip information, the field surveys were divided into two types. Firstly, the Household Interview (HHI) survey was conducted to gather daily personal trips made by KKU residents and others. The entire KKU area was divided into 59 zones and the number of conducted HHIs was approximately 2,000. Secondly, the Roadside Interview (RSI) survey was carried out to collect entry/exit/through trip data to and from the study area. This was undertaken at 6 main entrances of KKU with the sample size of the RSIs of around 6,000. The surveyed data derived from these two interviews are essentially vital for the development of the transport demand models for the KKU.

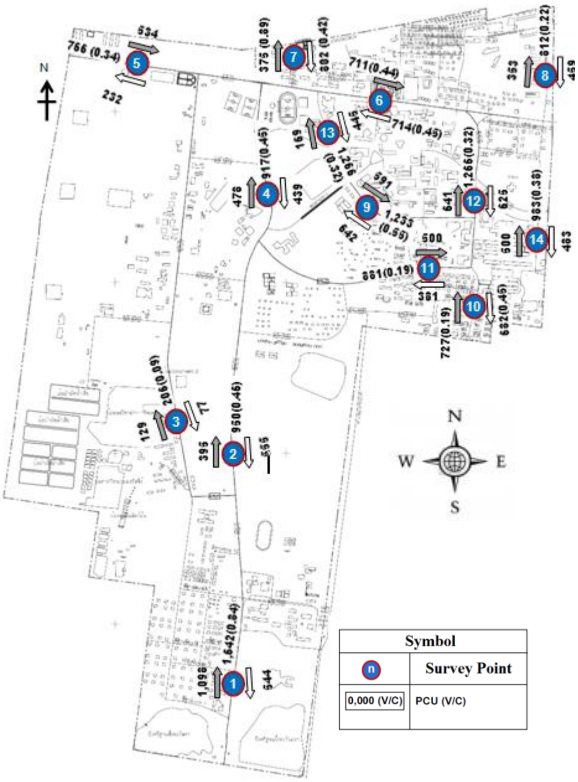


Figure 5. Mid-block traffic volumes and V/C in the morning peak hour period (TGO, 2012)

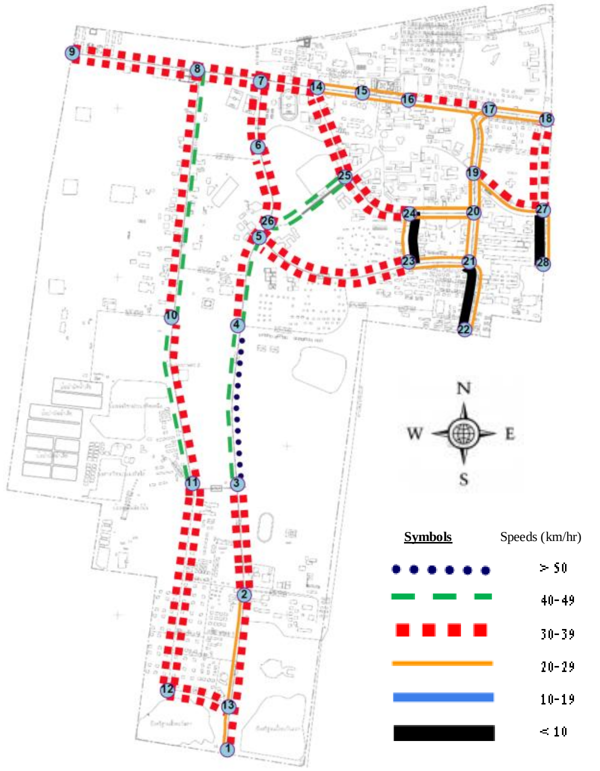


Figure 6. Mid-block average travel speeds in the morning peak hour period (TGO, 2012)

In this study, the sequential 4-step urban transport modeling technique was adopted. The developed model was subsequently calibrated and validated against another independent surveyed data set. The analysis result showed that the modeling travel patterns were reasonably comparable and consistent with the current actual travelling behaviors in the study area. The key indicators used in the calibration and validation processes were mid-block traffic volumes at certain selected streets. There were three scenarios developed for future travel demand prediction in 2016, 2021, and 2031 base-models, respectively. As the results of modeling, trip production/attraction, trip distribution and traffic assignment and its associated traffic volume/Capacity (V/C)values of the study area were illustrated in Figure 7, 8 and 9, respectively. The developed urban transport models will be employed to predict the travel demand in the specific future years in response to the changes in population and socio-economic conditions, road network development and traffic management implementation. The vital capability will importantly be used to examine and analyze the influences of the implementation of different proposed scenarios regarding the reduction of GHG emissions.

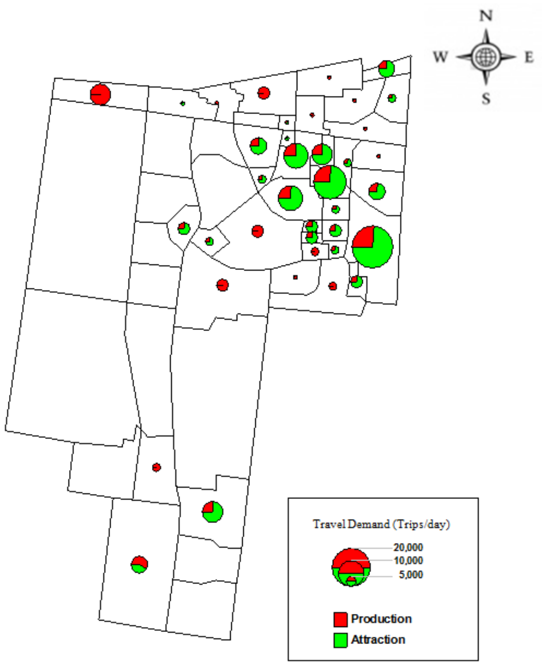


Figure 7. Trip Production/Attraction in the Study Area (TGO, 2012)

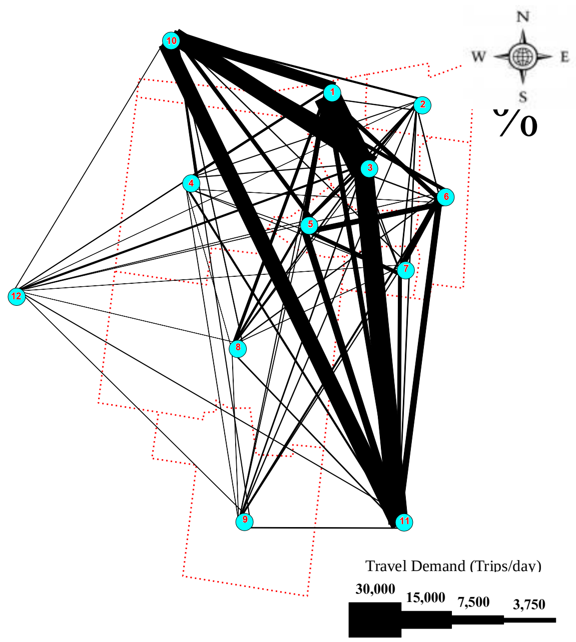
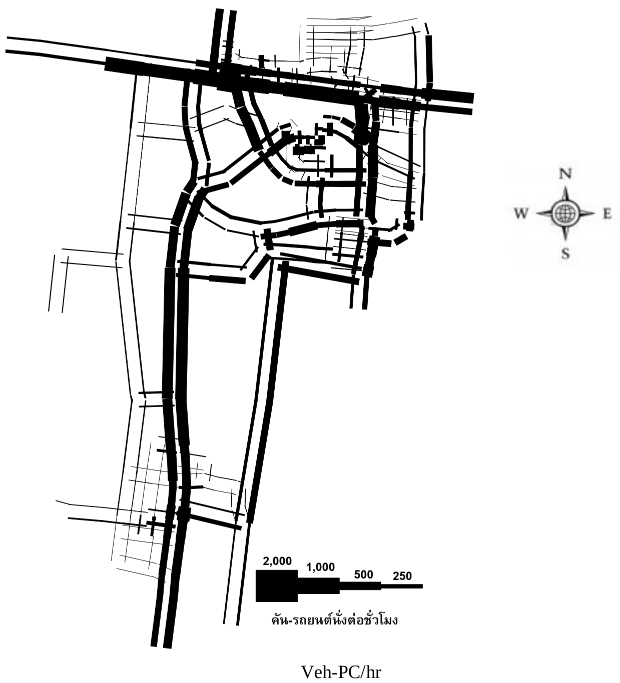


Figure 8. Trip Distribution in the Study Area (TGO, 2012)



Link Demand

Figure 9. Trip Assignment in 2011 (TGO, 2012)

5. BASELINE STUDY WITH BOTTOM-UP 2 APPROACH FROM ROAD NETWORKS

There are two principal approaches to the baseline methodology for estimating GHG emissions from transport projects. One is an approach to calculate GHG emissions from the consumption of fuels throughout the project, namely the *Top-Down Approach*,. The other is an approach to compute GHG emissions from the consumption of fuels of each vehicle or of each road section of the network related to the project, namely the *Bottom-Up Approach*. In this research, classified the approaches into three principal ones: OTP (2012)

- *The Top-Down Approach*: the main principles of the approach is to predict the volume of GHG emissions from the volume of fuels consumed by using statistical data of the fuels consumption to predict future consumption. Subsequently, the volume of the fuel consumption will be used in predicting the volume of GHG emissions by applying GHG emission factors of each fuel later.
- *The Bottom-Up 1 Approach*: the main principle of this approach is to predict the amount of GHG emissions of each vehicle and sum all the GHG emissions up. The total amount of GHG emissions will be the project emissions.
- *The Bottom-Up 2 Approach*: the key principle of the approach is to calculate the GHG emissions of the traffic volume running on each road (link) section of the considered road network and the total GHG emissions of each road section will be sum up to derive the total GHG emissions of the entire network. This approach is highly applicable to the utilization of the transport network modeling to estimate the traffic volume, vehicle classifications and average speeds within the entire network.

In this research, the Bottom-Up 2 approach was selected and adopted. This method can be applied for sequential 4-step urban transport planning model to estimate link-based traffic volumes and traffic speeds in the entire road networks, which can be calculated for GHG emission of the networks. The calculation process of the Bottom-Up 2 approach is illustrated in Figure 10.

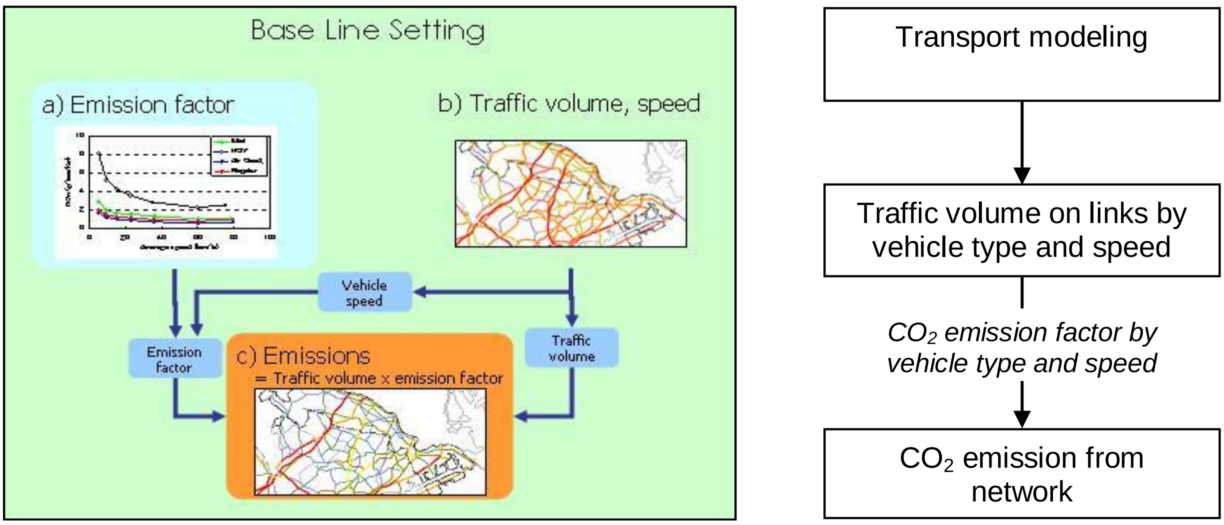


Figure 10. Estimation of the baseline GHG emission from road network by the Bottom-Up 2 approach (OTP, 2009)

6. ESTIMATIONSOF GHG EMISSION BY THE BOTTOM UP 2 APPROACH

The estimation of GHG emission from the road network will be based on the principle related to the link-based traffic volume and their associated link distance and average speeds in the road network during the determined time period. The traffic volume and average speed on each road link can be predicted by using the sequential 4-step urban transport planning models. GHG emission computations can be made by estimating an amount of GHG emission occurring from each vehicle class and each engine type on a road section (link). GHG emission quantity on each road link will be summation the of GHG emissions of every class of vehicles and all types of engines of every road link by using the equations relating GHG emission factors, the traffic volume and the traffic speeds of each vehicle type and each engine type (eg private cars, buses, trucks, and motorcycles, etc).The general equation is shown in the equation 1 (OTP, 2009).

$$TE = \sum(Ef_{ij} \ x \ D_e/1000 \ x \ V_{ije}) \quad (1)$$

where,

- TE :Total GHG emission from all vehicle type *i* and engine type *j* of all links (*e*) in a road network (grams)
- Ef_{ij} : Emission factor of vehicle type *i* and engine type *j* (grams)
- D_e : Road distances of link (*e*) (m)
- V_{ije} : Traffic volume of vehicle type *i* and engine type *j* on all links (*e*) (no. of veh/day)

Baseline methodology is the calculation of GHG emission reduction without the proposed project ('*Without Project*' scenario). *'With-Project'* scenario is the calculation of GHG emission reduction with one or more project proposed. The difference between GHG emission from baseline (without-project) scenario and with-project scenario are determined to estimate the potential GHG emission reduction according to the proposed project as shown in Figure 11.

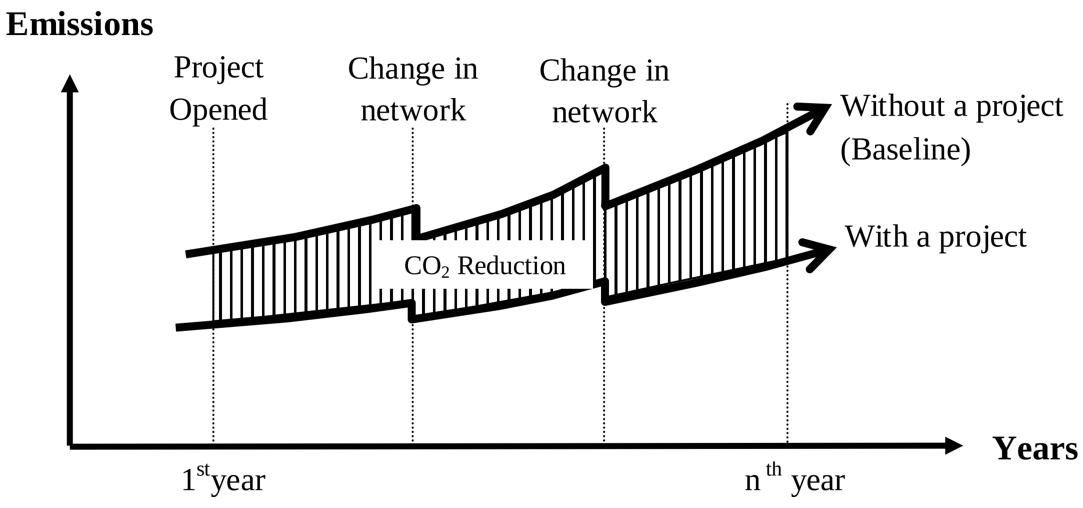


Figure 11. Determining GHG emission reduction from road networks
As the result of the proposed project (adapted from OTP, 2009)

7. THE EMISSION FACTORS FOR THE CALCULAIONS OF GHG EMISSION REDUCTION

The calculation results of baseline GHG emission in the study area are derived from the Bottom Up 2 approach. The key data required in the calculation are traffic volume categorized by types of vehicles and engines, average travelling speeds, and trip distance in each road section. In this study, only the amount of CO2 was considered due to its large proportion compared to other GHG types.

In the GHG emission calculation, the adopted emission factors were derived from the three previous projects, including *Study to Promote CDM Projects in Transportation Sector in Order to Resolve Global Environmental Problem (Bangkok Metropolitan Area Case* (MLIT, 2004), *the Feasibility Study for Clean Development Mechanism (CDM) in Transport sector: Phase II* (OTP, 2009) and *The Study from Pollution Control Department* (PCD, 2011). The selected types of vehicles adopted in the research are as follows: (i) passenger car (PC); (ii) motorcycle (MC); (iii) light duty truck (LDT); (iv) truck (T); (v) diesel bus (DB) and (vi) CNG bus (CNGB). An example of those emission factors used in this research is given in Figure 12.

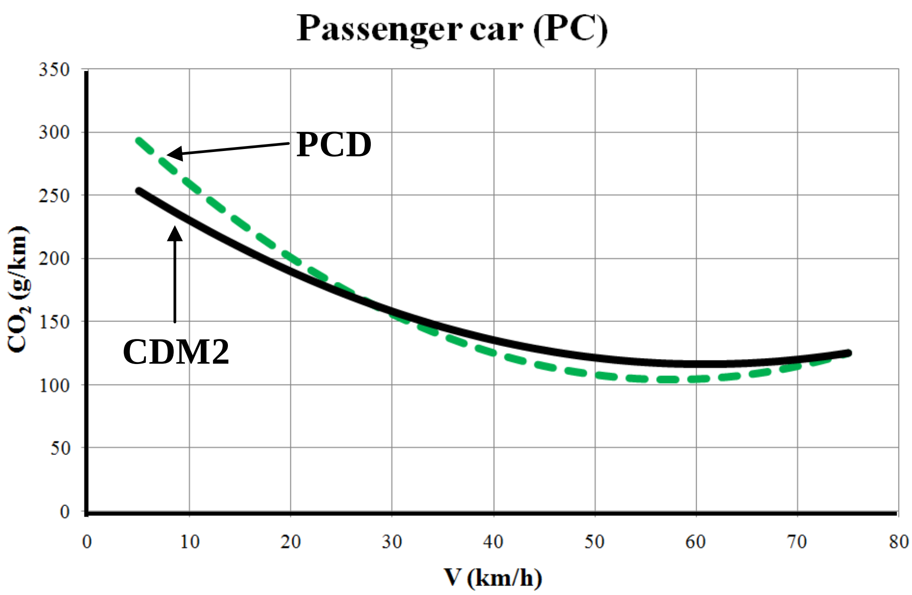


Figure 12. The adopted emission factors of passenger car developed by PCD (2011) and OTP (2009) Adapted from TGO (2012)

8. CONCEPT OF THE REDUCTION OF GHG EMISSION FROM TRANSPORT SECTOR IN THE STUDY AREA

In this research, the potential measures adopted to reduce GHG emission from the transport sector in the study area were carefully determined and selected. The potential measures were chosen based on the concepts suggested by May (2003) and GTZ (2007).The three most pronounced strategies used were Avoid (A), Shift (S) and Improve (I), in corresponding to the five key instruments including Planning instruments (P), Regulatory instruments (R), Economic instruments (E), Information instruments (I) and Technology instruments (T). These five instrumental policies were determined along with the regional factors (eg the road physical and land use characteristics, etc). Therefore, four selected scenarios expected to be highly effective in reducing GHG emission from the transport sector were investigated and evaluated. They were as follows (TGO, 2012):

- *Land Use Planning Strategy*, the planning (P) scenario of using mixed-use, one-center and compact land uses was adopted to minimize the traveling distance of most trips. This will consequently reduce the number of vehicles and travelled distances on the road network. Considering the existing land use patterns, residential zones in the southern part (Area 1) and in the northeastern part (Area 2) of KKU are recommended to be relocated to the new residential zones (Area 3) adjacent to the academic activities (one center) zone in the northern part of KKU as shown in Figure 13. This project was proposed in the recently completed master plan study and design of the study area (KKU,2009).

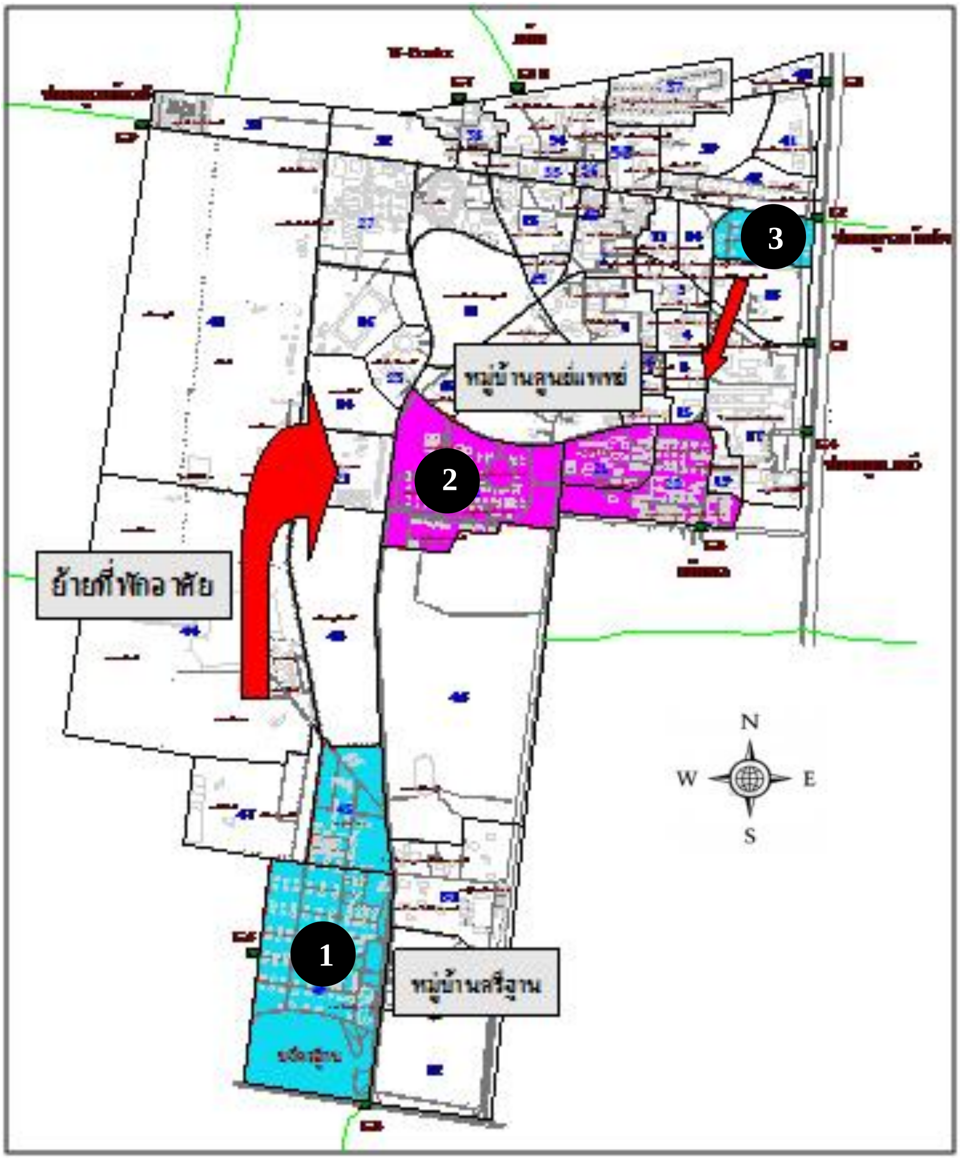


Figure 13. Land use planning scenario (TGO, 2012)

- *Public Transport Improvement Strategy*, the regulatory (R) scenario is to improve the public transport system in KKU by rerouting the service route networks of the "*Song-Thaew*" buses (para-transit mode) and public vans to support the services of (free of charge) shuttle bus system servicing within the KKU. Specifically, those "*Song–Thaew*" buses and public vans will allow providing their services only outside KKU perimeter, while the shuttle buses will serve passengers inside KKU and connect to those passengers from outside KKU by those "*Song–Thaew*" buses and public vans into KKU boundary. The bus service schedules will be adjusted, in terms of frequency and headway to match with the travel demand of those passengers.
- *Cleaner Technology Strategy*, this technological (T) scenario was proposed for the residents and others who live in KKU to replace their common (benzene) motorcycles with electrical (zero GHG emission) motorcycles. This regulatory campaign is expected to gain the utilization rate of electrical motorcycles of 25% (by 2021) and 50% (by 2031) of the total number of motorcycles in KKU.
- *Restriction of Private Vehicle Usage Strategy*, this regulatory (R) scenario was introduced for 1st year students of 3,585 students, who want to reside in the KKU dormitories inside the campus (approximately 8 percent of the total students). Those students will not allow using their common private vehicles (eg motorcycles, passenger cars, etc.). The basic assumption is that before implementing the strategy, all 1st year students who live in the KKU dormitories normally use common motorcycles, while after implementing the strategy, those students can only travel by using the KKU (free of charge) shuttle bus.

9. ANALYSIS RESULTS FROM GHGEMISSION REDUCTION SCENARIOS IN TRANSPORT SECTOR OF THE STUDY AREA

This section will discuss the analysis results of the GHG emission reduction from each proposed individual project and combined projects in the study area (TGO, 2012). Each of the four proposed individual scenarios is given below and the details of each scenario are previously discussed in section 8.

Scenario 1: Land Use Planning (P)
Scenario 2: Public Transit Improvement (R)
Scenario 3(A): Cleaner Technology (usage rate of electrical motorcycles of 25% of the total number of motorcycles) (T)
Scenario 3(B): Cleaner Technology (usage rate of electrical motorcycles of 50% of the total number of motorcycles) (T)
Scenario 4: Restriction of Private Vehicle Usage (R)

The integrated scenarios were also determined to investigate the effectiveness in reducing GHG emission from transport sector in road network. Four integrated scenarios are listed as follows:

Scenario 5: The integrated *Scenario 1* and *Scenario 2*
Scenario 6(A): The integrated *Scenario 1*, *Scenario2* and *Scenario 3(A)*
Scenario 6(B): The integrated *Scenario 1*, *Scenario2* and *Scenario 3(B)*
Scenario 7: The integrated *Scenario 1, Scenario2* and *Scenario 4*

The baseline CO2 emission estimated by employing CDM2, MLIT and PCD methods in the year 2011, 2021 and 2031 and the associated total trip distance and total travel time are presented in Table 1. It was found that the calculation using emission factors from CDM2 (OTP, 2009) yielded the lowest result (approximately 10% lower than MLIT (2004) and PCD (2011) that obtained similar results.

Table 1. The baseline CO2 emission and their associated total trip distance and total travel time in the study area in 2011, 2021 and 2031 (adapted from TGO, 2012)

Year	Total Trip Distance (Veh-km)	Total Travel time (Veh-hr)	Tons of CO_2 Emission (Tons/yr)		
			CDM2	MLIT	PCD
2011	36,867	932	9,868	11,883	11,518
2021	45,421	1,668	13,261	16,070	14,640
2031	54,745	2,510	17,008	20,329	18,542

The estimated GHG emission reductions for individual and integrated proposed scenarios by employing emission factors developed by CDM2, MLIT and PCD methods in 2021 and 2031 are presented in Tables 2 and 3, respectively.

Table 2. The calculatedCO2 emission reductions for different scenarios in 2021 (adapted from TGO, 2012)

Scenarios	Total Trip Distance Reduction (Veh-km)	Total Traveling Time Reduction (Veh-hr)	Ton of CO_2Emission Reduction (Tons/yr) (%)		
			CDM2	MLIT	PCD
(1)	1,073 (-2.36%)	48 (-2.88%)	352 (-2.65%)	535 (-3.33%)	326 (-2.23%)
(2)	227 (-0.50%)	6 (-0.36%)	129 (-0.97%)	166 (-1.03%)	122 (-0.83%)
(3A)	-	-	687 (-5.18%)	901 (-5.61%)	659 (-4.50%)
(3B)	-	-	1,506 (-11.36%)	1,813 (-11.28%)	1,830 (-12.50%)
(4)	1,617 (-3.56%)	60 (-3.60%)	212 (-1.60%)	255 (-1.59%)	270 (-1.84%)
(5) = (1)+(2)	1,300 (-2.86%)	55 (-3.30%)	308 (-2.32%)	503 (-3.13%)	215 (-1.47%)
(6A) = (1)+(2)+(3A)	1,300 (-2.86%)	55 (-3.30%)	1,054 (-7.95%)	1,400 (-8.71%)	1,292 (-8.83%)
(6B) = (1)+(2)+(3B)	1,300 (-2.86%)	55 (-3.30%)	1,799 (-13.57%)	2,297 (-14.29%)	2,189 (-14.95%)
(7) = (1)+(2)+(4)	2,885 (-6.35%)	144 (-8.63%)	517 (-3.90%)	754 (-4.69%)	646 (-4.41%)

Table 3.The calculated CO2 emission reductions for different scenarios in 2031 (adapted from TGO, 2012)

Scenarios	Total Trip Distance Reduction (Veh-km)	Total Traveling Time Reduction (Veh-hr)	Ton of CO_2Emission Reduction (Tons/yr) (%)		
			CDM2	MLIT	PCD
(1)	1,388 (-2.54%)	132 (-5.26)	490 (-2.88%)	615 (-3.03%)	522 (-2.82%)
(2)	227 (-0.41%)	8 (-0.32%)	89 (-0.52%)	79 (-0.39%)	120 (-0.65%)
(3A)	-	-	931 (-5.47%)	1,121 (-5.51%)	1,121 (-6.05%)
(3B)	-	-	1,862 (-10.95%)	2,241 (-11.02%)	2,241 (-12.09%)
(4)	1,953 (-3.57%)	92 (-3.67%)	260 (-1.53%)	314 (-1.54%)	314 (-1.69%)
(5) = (1)+(2)	1,615 (-2.95%)	135 (-5.38%)	570 (-3.35%)	762 (-3.75%)	626 (-3.38%)
(6A) = (1)+(2)+(3A)	1,615 (-2.95%)	135 (-5.38%)	1,480 (-8.70%)	1,857 (-9.13%)	1,721 (-9.28%)
(6B) = (1)+(2)+(3B)	1,615 (-2.95%)	135 (-5.38%)	2,389 (-14.05%)	2,951 (-14.52%)	2,816 (-15.19%)
(7) = (1)+(2)+(4)	3,522 (-6.43%)	226 (-9.00%)	825 (-4.85%)	1,069 (-5.26%)	933 (-5.03%)

In 2021, according to Table 2, *Scenario 3(B)* yields the highest potential in reducing GHG emission, followed by *Scenario 1*, *Scenario 4*, and *Scenario 2*, respectively. *Scenario 3A* was able to reduce the GHG emission of between 4.5% and 5.6% compared to those from the baseline scenario. *Scenario 1* was able to reduce the GHG emission of between 1.5% and 1.7%. *Scenario 2*, on the other hand, presented the lowest emission reduction of only 1% compared to the baseline results.

In 2031, referring to Table 3, *Scenario 3(B)* similarly had the highest potential in GHG emission reduction, followed by *Scenario 1*, *Scenario 4*, and *Scenario 2*, respectively. Moreover, the total GHG emission reduction compared to baseline scenario in 2031 showed similar findings to those in 2021. Only those of *Scenario 2* yielded only between 0.4% and 0.6% in 2031, whereas in 2021 it yielded approximately 1%.

When evaluating the GHG emission reduction capacity from transport sector in the study area of these main scenarios in 2021 and 2031, *Scenario 6B*(*Scenarios (1)+(2)+(3B)*) yields the greatest potential of the GHG emission reduction and followed by *Scenario 6A*(*Scenarios (1)+(2)+(3A)*), *Scenario 7*(*Scenarios (1)+(2)+(4)*) and *Scenario 5*(*Scenarios (1)+(2)*), respectively.

The implementation of cleaner technology strategy (*Scenario 3*) presented the highest potential capacity, followed by land use planning strategy(*Scenario 1*) and restriction of private vehicle usage (*Scenario 4*), respectively. The public transit improvement strategy (*Scenario 2*) showed the lowest potential capacity in GHG emission reduction. The potential capacity of the GHG emission reduction of the integrated scenarios of each of these four individual scenarios as represented by scenarios 5, 6 and 7 also consistently reflected the potential impacts of each individual scenario consisted in each of these integrated scenarios.

10. CONCLUSIONS

This paper presented the analysis and evaluation of implementing transport and land use measures in reducing GHG emissions generated from the transport sector. The study selected the Khon Kaen University (KKU) campus as a pilot study area. This covers approximately 900 hectares and includes more than 50,000 residents. It can represent and be an prototype example for a small town in others developing countries.

In the evaluation process, the study applied the Bottom-Up 2 approach, which can calculate the GHG emissions of all traffic volume running in the transport network. This process needed the utilization of the transport network modeling to estimate the traffic volume, vehicle classifications and average speeds within the entire network.

It was found that the calculation using emission factors from CDM2 (OTP, 2009) project yielded the lowest result; approximately 10% lower than MLIT (2004) and PCD (2011) which yielded relatively similar results.

Based on the potential capacity of the GHG emission reduction of the four individual proposed scenarios in 2021 and 2031, the implementation of cleaner technology strategy (*Scenario 3*) clearly showed the highest potential capacity, followed by land use planning strategy (*Scenario 1*) and restriction of private vehicle usage (*Scenario 4*), respectively. The public transit improvement strategy (*Scenario 2*) illustrated the lowest potential capacity.

When considering the potential capacity of the GHG emission reduction of each integrated scenario, it was found that *Scenario 6B*(*Scenarios (1)+(2)+(3B)*) yields the greatest potential of the GHG emission reduction and followed by *Scenario 6A*(*Scenarios (1)+(2)+(3A)*), *Scenario 7*(*Scenarios (1)+(2)+(4)*) and *Scenario 5*(*Scenarios (1)+(2)*), respectively. The potential capacity of the GHG emission reduction of the combination of these four individual scenarios represented as scenarios 5, 6 and 7 also consistently reflected their potential impacts of each individual scenario consisted in each integrated scenario.

For the policy implication, the results suggested:

- Implementing public transport improvement alone cannot achieve significant effect in reducing GHGs. This is because without any “push” policy, the public transport improvement can only encourage a small proportion of mode shift from motorcycles and cars.
- Implementing the integrated strategy, including compact land use, public transport improvement and private vehicle restriction (combination of “push” and “pull” policies), can achieve relatively significant effect. This is depended on the degree of implementation of each measure. To meet objectives of a city, optimization approach can help in selecting the best strategy (see an example in May et al., 2005). However, public acceptability is a key issue in the success of the implementation process. Highly effective strategy may be less acceptable to the public, but highly acceptable strategy may be less effective. Thus, designing an appropriate strategy with timing for implementation should be studied in detail.
- Although, the impacts of the cleaner technology are highly significant in reducing the GHGs, but achieving the utilization rate of electrical motorcycles up to 50% is not straightforward and not in a short term. It is depended on many factors, e.g. vehicle price, maintenance cost, provision of electric charging facilities, users’ perception on

the technology, etc. Furthermore, it is unlikely to be implemented at the local level. It needs support from the national policy.

Finally, it should be noted that the analysis in this study presents only one dimensional view, which is to evaluate GHG emission reduction. In reality, there are several direct and indirect benefits to each scenario which were not mentioned here. Moreover, costs and investments required for the implementation also vary. For example, some projects presenting high potential in emission reduction might also require enormous amount of financial investment, whereas some yield lower potential but requires much smaller investment. Therefore, the results from this should not solely be the indicator of project feasibility in the study area. Further study is needed in the economic analysis of the emission and fuel consumption reduction, in order to cover other aspect of the project (see an example in Hensher (2008)).

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