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

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).

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

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.

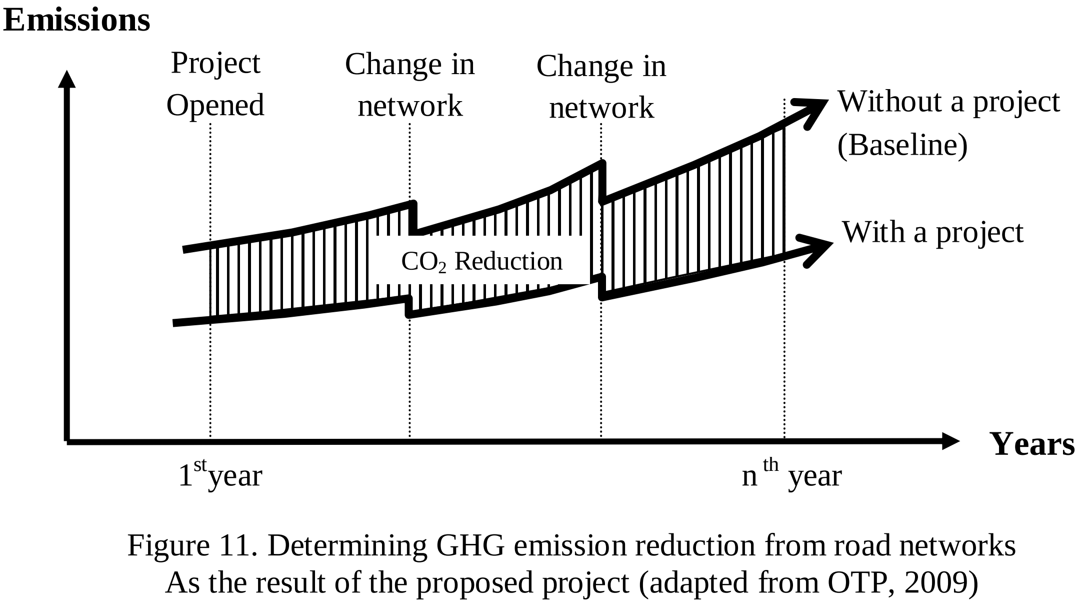

Figure 11. Determining GHG emission reduction from road networks
As the result of the proposed project (adapted from OTP, 2009)

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.

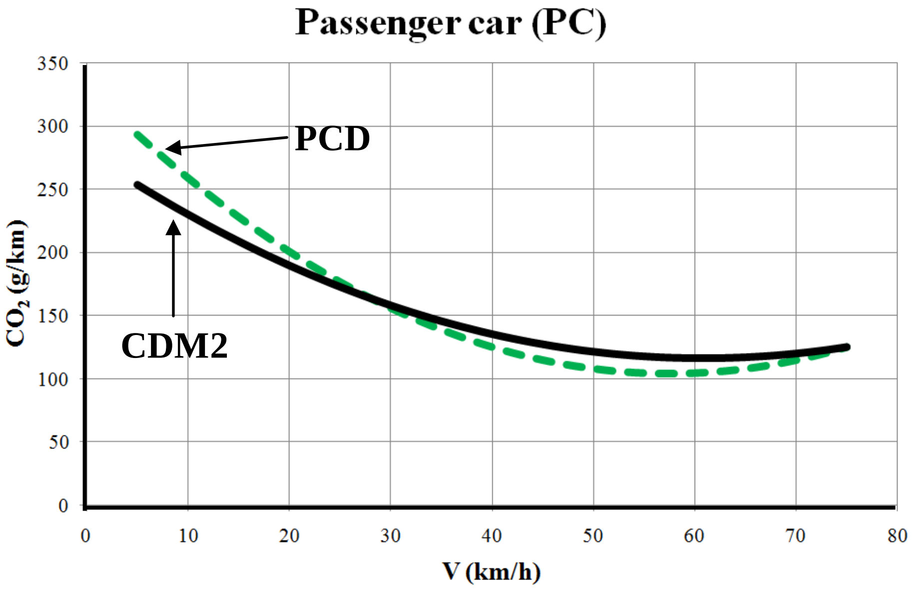

Figure 12. The adopted emission factors of passenger car developed by PCD (2011) and OTP (2009) Adapted from TGO (2012)

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).

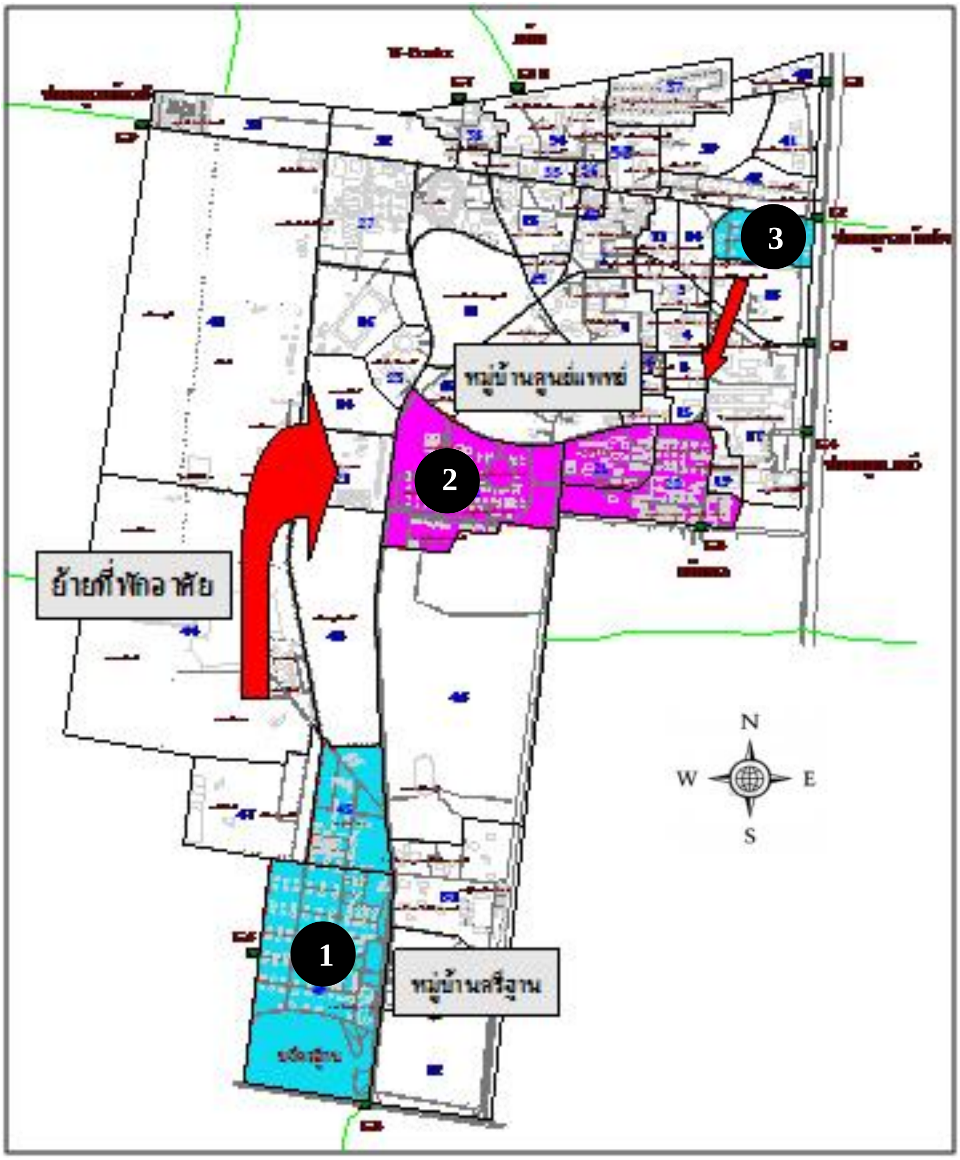

Figure 13. Land use planning scenario (TGO, 2012)

- *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$_2$Emission 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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