EMISSION IMPACT ASSESSMENT OF HARBIN BUS PRIORITY CORRIDOR

Final Report

CLEAN AIR ASIA

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About Clean Air Asia (www.cleanairasia.org)

Clean Air Initiative for Asian Cities (Clean Air Asia) promotes better air quality and livable cities by translating knowledge to policies and actions that reduce air pollution and greenhouse emissions from transport, energy, and other sectors.

Clean Air Asia was established as the leading air quality management network for Asia by the Asian Development Bank, World Bank and USAID in 2001, and operates since 2007 as an independent non-profit organization. Clean Air Asia has offices in Manila, Beijing and Delhi, networks in eight Asian countries (China, India, Indonesia, Nepal, Pakistan, Philippines, Sri Lanka, and Vietnam) and is a UN recognized partnership of almost 250 organizations in Asia and worldwide.

Clean Air Asia uses knowledge and partnerships to enable Asia's 1,000+ cities and national governments understand the problems and identify effective policies and measures. Our four programs are: Air Quality and Climate Change, Low Emissions Urban Development, Clean Fuels and Vehicles, and Green Freight and Logistics.

The biennial Better Air Quality (BAQ) conference is the flagship event of Clean Air Asia bringing experts, policy and decision makers together to network, learn and share experiences on air quality management. Past BAQs have proven to influence policies, initiate new projects and establish partnerships.

LIST OF ABBREVIATIONS

ADB	Asian Development Bank
BAQ	Better Air Quality
BRT	Bus Rapid Transit
FSR	Feasibility Study Report
GEF	Global Environment Facility
ICCT	International Council on Clean Transportation
ITDP	Institute for Transportation & Development Policy
KM	Kilometer
Kmph	Kilometer per hour
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
NO_x	Nitrogen Oxides
PM	Particulate Matter
TEEMP	Transport Emissions Evaluation Models for Projects
UNEP	United Nations Environment Programme

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1. INTRODUCTION

1.1 Project Background

The World Bank is preparing a "Cold Weather Smart Public Transportation System" project in Harbin, Heilongjiang Province, China (hereinafter referred to as "Harbin project"). Considering the severe air pollution situation in China, the World Bank is putting together a team of experts to incorporate air quality management into the Harbin Project, and thus Clean Air Asia is commissioned by the World Bank to apply the Transport Emissions Evaluation Models for Projects (TEEMP) tool to assess potential reductions in air pollutants and CO_2 emissions of the bus priority corridor component of the Harbin Project.

1.2 Harbin Bus Priority Corridor

Based on the Harbin project feasibility study report (FSR), the planned 3 bus priority corridors are located in very important areas gathering transportation, administration, science and technology, commercial, residential and industrial functions. The routes and number of bus lines and stops of the 3 planned bus priority corridors are listed below.

Table 1 Routes of the Harbin Bus Priority Corridors

Road Name	Road Level	Length(KM)
YOUYI Road	Arterial Road	8.5
HONGQI Avenue	Arterial Road	9.1
XINYANG Road	Arterial Road	3.95
Total		**21.55**

Figure 1 Transport Projects Emissions Savings Calculation

Table 2 Bus Lines and Stops Converging Along the Three Bus Corridors

Road Name	Number of Bus Lines	Number of Bus Stops
YOUYI Road	28	17
HONGQI Avenue	36	18
XINYANG Road	19	8
Total	**83**	**43**

1.3 TEEMP Description

Estimating emissions from transport is an important element in analyzing current and future transport scenarios in cities. Currently, cities embark on investing in transport infrastructure without adequately estimating the repercussions on the environment and climate. Traditional tools and methodologies for evaluating the emission impacts of such projects may require extensive resources in terms of time, data and finance. Thus, methodologies and tools that enable the rapid but sound assessment of the emission impacts of transport projects using readily available data are much needed to promote investment in the transport sector. This created a necessity for simple excel-based models which can be used easily in projects.

Thus, in 2010, the CAI-Asia Center (now Clean Air Asia), together with Institute for Transportation & Development Policy(ITDP), Asian Development bank (ADB), Cambridge Systematics and the United Nations Environment Programme (UNEP) – Global Environment Facility (GEF) Scientific and Technical Advisory Panel, developed excel-based, free-of-charge spreadsheet models collectively called "Transport Emissions Evaluation Models for Projects" (TEEMP). The TEEMP tool was initially developed for evaluating the emissions impacts of ADB's transport project and has been modified and extended for GEF projects. The third generation models have been tested with support from ADB and the World Bank. In its current form, TEEMP can be easily applied for evaluating the ex-ante impacts of various transport measures at project level. [1,2] TEEMP tool has been used in more than 20 cities to evaluate the impact of various types of transport projects.

TEEMP tool is built to be operationally flexible. It can provide sketch estimates with minimum data, making use of data that is readily available from project feasibility studies and project plans that should otherwise be produced in order to determine the economic and transportation-related outcomes of the project. In the meantime, it can conduct detailed estimates with more intensive data to encourage better evaluations. Transport sector in many developing countries have inadequate data to provide robust estimates and thus TEEMP provides a set of default values based on available and current literature.

TEEMP primarily evaluates the impacts of transport projects on CO_2 emissions and to some extent air pollutant emissions (PM and NO_x) using data gathered during project feasibility and actual operations. By using TEEMP, analysts have an opportunity to examine the project's emissions impacts both at ex-ante and ex-post stages and include these quantifications in the economic analysis or in the monitoring of the project's impacts.

[1] ADB 2010. Reducing Carbon Emissions from Transport Projects. See: http://www.adb.org/Documents/Evaluation/Knowledge-Briefs/REG/EKB-REG-2010-16/default.asp

[2] GEF STAP 2010. Manual for Calculating Greenhouse Gas Benefits for Global Environmental Facility Transportation Projects. See: http://www.thegef.org/gef/GEF_C39_Inf.16_Manual_Greenhouse_Gas_Benefits

1.4 TEEMP Methodology for Harbin Bus Priority Corridor

The bus priority corridor emissions model captures the impact of Bus Rapid Transit (BRT) on CO_2 emissions by quantifying the construction, operation and traffic impacts of projected bus priority corridor users. It is assumed that in case the bus priority corridor would not have been constructed, the users would have been forced to use the existing modes and thus the emissions saved results from quantifying the business as usual case of the proposed bus priority corridor riders. The boundary of quantification is fixed across the bus priority corridor riders only.

Emissions saved from bus priority corridor = Emissions from bus priority corridor riders using alternate modes without bus priority corridor – Operation emissions of bus priority corridor – construction emissions from bus priority corridor

The primary savings are derived from the mode shift impacts and increase in speed and occupancy factors. The impact on the movement of other modes of transport (for instance, speed increase, or vehicles which people used earlier to make the trip are still being used perhaps by another family member after the bus priority corridor has been constructed) is neglected. Inclusion of this aspect would require not only data–intensive traffic modelling but also a city-wide additional surveys and the accuracy would still depend on several network factors and information on link, future projects or investments. Currently, such kind of benefits are not reflected in the vehicle operating cost and travel time savings which are calculated during feasibility stage which have greater economic value when compared to CO_2 savings. It may not be justifiable to conduct city-wide surveys just for the quantification of the CO_2 benefits.[3]

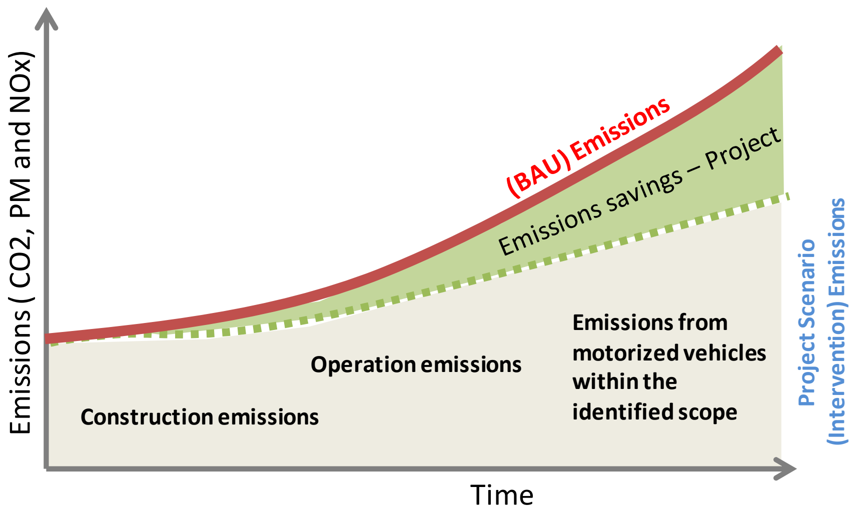

Figure 2 Transport Projects Emissions Savings Calculation

Currently, the TEEMP models do not account for emissions from idling, particularly cold-start idling. Since Harbin is a well-known winter city, cold-start idling and warm up for buses is a source of emissions, underground heated garages are proposed in the Harbin bus priority corridor project in order to avoid idling emissions. The emission impact of such cold-start idling reduction will be calculated using the following framework:

[3] Schipper, el al. (2010) found that in a Mexico metro bus project, if CO2 is valued even at USD$85/tonne, the CO2 co-benefits add almost USD $4m to the total, and the CO2 is worth about 20% of the total project benefits. Available: http://metrostudies.berkeley.edu/.../shipper-considclimatechange-latinamer.pdf

Emission from idling can be obtained from Eq. 1.

$$E_j = \sum_{i=1}^{3} (t_n \times d_n) \times 400 \times EF_j \times 20$$ Eq. 1

Where:

E_j is emission of species j from idling
t_n is time used to start vehicle in scenario n
d_n is operation days in scenario n
EF_j is emission factor of specie j

Emission from coal burning for heated garages can be obtained from Eq. 2.

$$E'_j = \sum_{i=1}^{3} \left(\frac{P_{r,m}}{P_{t,m}} \times \frac{M_m}{b} \right) \times EF_j \times 20$$ Eq. 2

Where:

E_j' is emission of species j from coal burning
$P_{r,m}$ is power load of underground terminal in terminal m
$P_{t,m}$ is total power load of the terminal m
Mm is heat consumption in terms of coal equivalence, tonnes
b is coefficient of standard coal to raw coal
EF_j is emission factor of specie j

Thus, total emission reduction by construction of heated garages to reduce idling emission can be obtained from Eq. 3.

$$E = E_j - E_j'$$ Eq. 3

2. DATA USED for TEEMP ASSESSMENT

Based on TEEMP model design, data needs to be collected and inserted into excel-based spreadsheet to calculate the emission savings of any individual transport project. In this study, Clean Air Asia collected data from the documents provided by the World Bank and institutions engaged in the Harbin Project design. Where data required for TEEMP assessment has not been available in the documents provided to Clean Air Asia, default values were used and conservative assumptions were made. Data sources are stated where relevant data is presented in this chapter.

2.1 Project Duration

Project analysis is carried out for 20 years. For the Harbin bus priority corridor project, start year is assumed to be 2015, with a final forecast horizon year of 2034[4].

2.2 Ridership Projections

Two demand scenarios[5] are forecasted for the Harbin bus priority corridor - the alternative scenario, where the bus priority corridor is implemented and business-as-usual scenario without the project in years 2015, 2020, 2023, 2025 and 2030. According to the transport demand forecast with peak hour factor of 13%, the ridership of the bus priority corridor per day are showed in the table below. Therefore, a growth rate of 10% or more bus ridership in bus priority corridor scenario is projected.

Table 3 Harbin Bus Priority Corridor Ridership Forecast

	2015	2024	2034
Bus Corridor Ridership - ('000)/day	261.46	341.15	458.47

2.3 Existing Trip Mode Share

The forecasting result[6] suggests that public transport share will be increased to 40% in 2020 and 45% in 2030. With the construction of bus priority corridor system, the average speed of those 3 bus priority corridors will be increased to 20 kilometres per hour or more, comparing with no bus priority corridors scenario.

The mode shift to the bus priority corridor from other modes is assumed based on the existing trip mode share[7]shown below.

[4] The construction of 3 lanes will be finished step by step from 2014 to 2016, 2015 as the middle of construction is chosen to be the base year.

[5] Data source: Report of Investigation and Analysis of Integrated Transport Demand Forecast prepared by Transportation Research Center of Northeast Forestry University for the Harbin bus priority corridor, September 2013.

[6] Data source: Report of Investigation and Analysis of Integrated Transport Demand Forecast prepared by Transportation Research Center of Northeast Forestry University for the Harbin bus priority corridor, September 2013.

[7] Data source: Report on "GEF Project Carbon Emission Reduction Estimation in Harbin" and Harbin Project Feasibility Study Report

Table 4 Forecast Mode Shift to Bus Priority Corridor in Years 2015, 2024 and 2034

Vehicle Type	2015	2024	2034
Car	6%	8%	10%
2-wheeler	1%	1%	1%
Taxi	8%	7%	6%
Bus	67%	65%	62%
Other	18%	19%	21%

The above mode shift is considered using mode share data of 2011 in Harbin and factoring motorization growth rates i.e. growth rates 6.55% (2015-2025) and 4.85% (2025-2030) and forecasting mode shares over the 20 years of project lifecycle. "Other" means other vehicle type, including mini bus and shuttle bus which is not included in the public bus system.

2.4 Existing Trip Length

The average trip length of passengers in bus priority corridor assumed is 11.8, 14.3 and 14.3 KM respectively in 2015, 2024, 2034[8].

2.5 Speed

The speed of main other transport modes are suggested[9] as below:

Table 5 Average Speed by Mode for Years 2015, 2024 and 2034

	Average Speed (kilometer/hour)		
Vehicle Type	2015	2024	2034
Cars	29	29	29
2-Wheeler	22	22	22
Taxi	29.7	29.7	29.7
Bus	18.9	18.9	18.9

The bus priority corridor average speed is considered as 30km/h based on the Harbin Project FSR. The TEEMP models use the average speeds and emission factors proposed for 50kmph.

2.6 Fuel Type, Emission Standards and PM and NO_x Emission Factors

In order to capture this impact of the bus priority corridor, the fuel split, emission standards, distribution of vehicles are considered based on data from the Communications Bureau of Harbin. According to the roadmap for fuel split and emission standards for China from Transport Roadmap Model developed by the International Council on Clean Transportation (ICCT), new light vehicles and buses should meet Euro IV equivalent emissions standards within 2013, and the assumption for future 20 years is Euro IV equivalent as well. LNG powered buses are considered for the bus corridor as designed in the project. The 2 wheels and 3 wheels should meet Euro III in 2013.

Of the limitations of this study is use of general emission factors based on ICCT Roadmap model and expert judgement as Harbin does not have local emission factors for different vehicle emission standards.

[8] Data source: Report on "GEF Project Carbon Emission Reduction Estimation in Harbin", prepared by GEF Project Management Office (Harbin), 2011.

[9] Data source: Report on "GEF Project Carbon Emission Reduction Estimation in Harbin", prepared by GEF Project Management Office (Harbin), 2011.

The tables below summarize the emission factors assumed in this project.

Table 6 Fuel Split by Mode

Fuel split	Petrol	Diesel	LPG	LNG	Electric
Car	93%	7%	0%	0%	0%
2-wheeler	100%	0%	0%	0%	0%
Taxi	86%	14%	0%	0%	0%
3-wheeler	1%	99%	0%	0%	0%
Bus	34%	39%	1%	25%	0%

Table 7 Technology Split by Mode for Years 2015, 2024 and 2034

	Technology Split (%)											
	2015				2024				2034			
Vehicle Type	Euro I	Euro II	Euro III	Euro IV	Euro I	Euro II	Euro III	Euro IV	Euro I	Euro II	Euro III	Euro IV
Car	0.080	0.004	0.212	0.586	0	0	0.008	0.991	0	0	0	1
2-wheeler	0.001	0.121	0.878		0	0	1		0	0	1	
Taxi	0.080	0.004	0.212	0.586	0	0	0.008	0.991	0	0	0	1
3-wheeler	0	0.204	0.796			0	1			0	1	
Bus	0.019	0.231	0.252	0.467	0	0.006	0.025	0.969	0	0	0	1
Bus Priority Corridor	0.019	0.231	0.252	0.467	0	0.006	0.025	0.969	0	0	0	1

Table 8 PM Emission Factors for Gasoline, Diesel (gram/vehicle-kilometer)

Gasoline

Vehicle Type	2015					2024					2034				
	Pre-Euro+Euro I	Euro II	Euro III	Euro IV	Average	Pre-Euro+Euro I	Euro II	Euro III	Euro IV	Average	Pre-Euro+Euro I	Euro II	Euro III	Euro IV	Average
Car	0.08	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	-	0.01	0.01	0.01	0.01
2-wheeler	-	0.02	0.01	0.01	0.012297	-	0.02	0.01	0.01	0.01	-	0.02	0.01	0.01	0.01
Taxi	0.09	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	-	0.01	0.01	0.01	0.01
3-wheeler	-	0.02	0.01	0.01	0.01	-	0.02	0.01	0.01	0.01	-	0.02	0.01	0.01	0.01
Bus	0.14	0.04	0.04	0.03	0.03	-	0.04	0.04	0.03	0.03	-	0.04	0.04	0.03	0.03
other	.07	0.01	0.01	0.01	0.01	-	0.01	0.01	0.01	0.01	-	0.01	0.01	0.01	0.01

Diesel

Vehicle Type	2015					2024					2034				
	Pre-Euro+Euro I	Euro II	Euro III	Euro IV	Average	Pre-Euro+Euro I	Euro II	Euro III	Euro IV	Average	Pre-Euro+Euro I	Euro II	Euro III	Euro IV	Average
Car	0.46	0.15	0.08	0.06	0.07	0.49	0.15	0.08	0.06	0.06	-	0.15	0.08	0.06	0.06
2-wheeler	0.00	0.16	0.09	0.04	0.10	-	0.16	0.09	0.04	0.09	-	0.16	0.09	0.04	0.09
Taxi	0.69	0.15	0.08	0.06	0.07	0.49	0.15	0.08	0.06	0.06	-	0.15	0.08	0.06	0.06
3-wheeler	-	0.16	0.10	0.05	0.11	-	0.16	0.10	0.05	0.10	-	0.16	0.10	0.05	0.10
Bus	1.05	0.21	0.13	0.11	0.14	-	0.21	0.13	0.11	0.11	-	0.21	0.13	0.11	0.11
other	0.33	0.08	0.08	0.06	0.07	-	0.08	0.08	0.06	0.06	-	0.08	0.08	0.06	0.06

Table 9 NO_x Emission Factor for Gasoline, Diesel (gram/vehicle-kilometer)

Gasoline

Vehicle Type	2015					2024					2034				
	Pre-Euro+Euro I	Euro II	Euro III	Euro IV	Average	Pre-Euro+Euro I	Euro II	Euro III	Euro IV	Average	Pre-Euro+Euro I	Euro II	Euro III	Euro IV	Average
Car	2.50	1.30	0.97	0.69	0.71	3.19	1.30	0.97	0.69	0.69	-	1.30	0.97	0.69	0.69
2-wheeler	0.00	0.16	0.11	0.09	0.11	-	0.16	0.11	0.09	0.11	-	0.16	0.11	0.09	0.11
Taxi	3.30	1.30	0.97	0.69	0.71	3.19	1.30	0.97	0.69	0.69	-	1.30	0.97	0.69	0.69
3-wheeler	-	0.64	0.40	0.34	0.45	-	0.64	0.40	0.34	0.40	-	0.64	0.40	0.34	0.40
Bus	4.78	3.96	3.35	3.35	3.34	-	3.96	3.35	3.35	3.35	-	3.96	3.35	3.35	3.35
other	-	0.90	1.00	0.22	0.56	-	0.90	1.00	0.22	0.24	-	0.90	1.00	0.22	0.22

Diesel

Vehicle Type	2015					2024					2034				
	Pre-Euro+Euro I	Euro II	Euro III	Euro IV	Average	Pre-Euro+Euro I	Euro II	Euro III	Euro IV	Average	Pre-Euro+Euro I	Euro II	Euro III	Euro IV	Average
Car	1.28	0.87	0.87	0.35	0.44	1.36	0.87	0.87	0.35	0.35	-	0.87	0.87	0.35	0.35
2-wheeler	0.00	0.27	0.18	0.15	0.19	-	0.27	0.18	0.15	0.18	-	0.27	0.18	0.15	0.18
Taxi	1.92	0.87	0.87	0.35	0.44	1.36	0.87	0.87	0.35	0.35	-	0.87	0.87	0.35	0.35
3-wheeler	-	0.64	0.40	0.34	0.45	-	0.64	0.40	0.34	0.40	-	0.64	0.40	0.34	0.40
Bus	10.47	6.95	5.56	3.19	4.53	-	6.95	5.56	3.19	3.27	-	6.95	5.56	3.19	3.19
other	1.13	0.85	0.48	0.45	0.53	-	0.85	0.48	0.45	0.45	-	0.85	0.48	0.45	0.45

Table 10 CO_2 Emission Factor for Gasoline, Diesel (kg/liter)

Gasoline

Vehicle Type	2015					2024					2034				
	Pre-Euro+Euro I	Euro II	Euro III	Euro IV	Average	Pre-Euro+Euro I	Euro II	Euro III	Euro IV	Average	Pre-Euro+Euro I	Euro II	Euro III	Euro IV	Average
Car	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40
2-wheeler	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40
Taxi	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40
3-wheeler	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40
Bus	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40
other	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40	2.40

Diesel

Vehicle Type	2015					2024					2034				
	Pre-Euro+Euro I	Euro II	Euro III	Euro IV	Average	Pre-Euro+Euro I	Euro II	Euro III	Euro IV	Average	Pre-Euro+Euro I	Euro II	Euro III	Euro IV	Average
Car	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60
2-wheeler	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60
Taxi	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60
3-wheeler	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60
Bus	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60
other	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60

Note: “Pre-Euro+Euro I” refers that it weights average of Pre-Euro and Euro I which depends on the % split of the modes.

2.7 Occupancy of Vehicles

Vehicle occupancy for different modes has been assumed based on TEEMP default value.

Table 11 Expected Vehicle Occupancy by Mode for Years 2015, 2024 and 2034

	Occupancy		
	2015	**2024**	**2034**
Car	2.38	2.38	2.38
2-wheeler	1.26	1.26	1.26
Taxi	2.38	2.38	2.38
3-wheeler	1.92	1.92	1.92
Bus	40	40	40
Other	39	39	39
Bus priority corridor	40	40	40

2.8 Fuel Efficiency at 50 kmph

The TEEMP model calibrates the fuel efficiency of different modes at different speeds using insights from existing models such as COPERT, CORINAR etc. The fuel efficiency at 50 kmph is factored and lowered as per the speed reductions. The current fuel efficiency values have been taken from Harbin local taxi and bus firm, TEEMP default values based on expert judgement as no local studies are available on fuel consumption of vehicles. The fuel consumption values proposed are adjusted with speed and thus on road fuel consumption values are generated inside the model. The table below gives the average fuel consumption values at 50kmph speed and TEEMP analyzes values for fuel efficiency for Harbin speed.

Table 12 Fuel Efficiency by Mode and Fuel Type

	TEEMP analyzed for Harbin Speed	
	Petrol (km/liter)	**Diesel (km/liter)**
Car	6	14.20
2-wheeler	55.66	1.10
Taxi	6	14.29
3-wheeler	25	14.29
Bus	15	17.5
Bus priority corridor	25.27 (LNG)	

2.9 Bus Priority Corridor Components

The ridership and speed is sensitive to the bus priority corridor design and hence borrowing insights from ITDP's bus priority corridor design guide and its working experience on Asian bus priority corridor systems, a concept of ridership depreciation is proposed to observe the impacts of various components on emissions in TEEMP bus priority corridor model. The bus priority corridor Standard proposed by ITDP and others follows a new scoring system to establish a broad, global understanding of what defines world-class bus priority corridor (or BRT) systems. The bus priority corridor Standard outlines best practices and case studies, and introduces a universal standard to recognize leaders and compare bus priority corridor systems[10].

[10]http://www.itdp.org/index.php?/microsites/brt-standard/

The Harbin Bus Priority Corridor is assumed to consist of following elements based on the FSR:

Table 13 Harbin Bus Priority Corridor Component Scores

Component	**Existing System**	**GREEN BUS CORRIDOR**
Service Planning		
Off-vehicle fare collection and fare verification	0	0
Multiple routes use same BRT infrastructure	4	4
Peak period frequency	4	4
Off-peak frequency	3	3
Limited and local stop services	2	3
System control center	2	3
Routes in top 10 demand corridors	2	2
Operates late nights and weekends	1	1
Part of (planned) multi-corridor BRT network	0	2
Infrastructure		
Bus lanes in central verge of the road	7	7
Physically-separated right-of-way	0	7
Intersection treatments	5	5
Physically-separated passing lanes at station stops	1	4
Stations set back from intersections	3	3
Stations are in center and shared by both directions of service	0	3
Emissions standards	2	3
Pavement quality	2	3
Station Design and Station-Bus Interface		
Platform-level boarding	3	6
Safe, wide, attractive weather-protected stations	2	3
3+ doors on articulated buses or 2+ very wide doors on standard buses	3	3
Multiple docking bays and sub-stops	0	0
Sliding doors at BRT stations	0	0
Quality of Service and Passenger information Systems		
Branding of vehicles and system	0	0
Passenger information at stops and on vehicles	0	0
Integration and Access		
Universal access	3	3
Integration with other public transport	2	3
Improved safe and attractive pedestrian access system and corridor environment	2	2
Secure bicycle parking at station stops	0	0
Bike lanes on corridor or on parallel streets	2	2
Bicycles permitted on vehicles	0	0
Bicycle sharing systems at BRT stations	0	1
Point Deduction		
Minimum average commercial speed below 13kph/8mph	-10	0
Peak passengers per hour per direction (pphpd) below 1,000	-5	-5
Lack of enforcement of right-of-way	0	0
Significant gap between bus floor and station platform	-5	-5
Bus stop/station encroaches on sidewalk or busway	-3	-3
Overcrowding	-3	-3
Poorly maintained buses and stations	0	0
Distances between stations too long or too short	0	0
TOTAL SCORE	**29**	**64**
Ridership Bonus Factor		**1.07**

2.10 Idling Emission

Since Harbin is an extremely cold city, it takes from 10 minutes to 45 minutes in cold weather to start the engine before the vehicle can be normally operated and considerable amount of emission is generated during this process. As a result, underground heated garages are proposed in the Harbin Green Bus Project in order to avoid idling emissions. However, the emission resulted from municipal heat supply, mainly from coal burning, to the heated garages should also be taken into consideration. Emission factors for idling were adopted from Frey et al. (2008) and listed in Table 14 with other data collected from Harbin Project FSR, relevant documents developed by National Development and Reform Commission (NDRC) and provided by Word Bank staff.

Table 14 Data Used to Calculate Idling Emission

Vehicle number per day[11]	400		
Time to start vehicle without heated garage[12]	Scenario (n)	Time used (t_n, min)	Operation days (d_n)
	< -20°C	45	90
	- 20°C to -15°C	30	45
	-15°C to 0°C	10	45
Power load in the bus terminal[13]	Terminal (m)	Total power (P_t, kW)	Power in heated garage (P_r, kW)
	Xiangbin	2211	711
	Qunli	670	360
Annual heat consumption[14]	Xiangbin (M_1, tonnes)	Qunli (M_2, tonnes)	
	714.43	210.24	
Emission factors for idling[15]	NO_x (g/h)	PM (g/h)	CO_2 (g/h)
	68.40	0.32	3168
Emission factor for coal burning	NO_x (g/kg)[16]	PM (g/kg)[17]	C (t/TJ)[18]
	7.1	1.2	26.37
Calorific value[19]	20.9 (TJ/kt)		
Oxidation rate of carbon[20]	94%		
Coefficient of standard coal to raw coal (b)[21]	0.7143 kgce/kg		

The emission factor of CO_2 for coal burning is converted based on the value from documents[22] from National Development and Reform Commission and presented in Eq. 4.

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[11] Data provided by WB staff.

[12] Data provided by WB staff.

[13] Harbin Project Feasibility Study Report.

[14] Harbin Project Feasibility Study Report.

[15] Frey, H. C., Rouphail, N. M., & Zhai, H. (2008). Link-based emission factors for heavy-duty diesel trucks based on real-world data. Transportation Research Record: Journal of the Transportation Research Board, 2058(1), 23-32.

[16] Q. Zhang, D. G. Streets, G. R. Carmichael, K. B. He, H. Huo, A. Kannari, Z. Klimont, I. S. Park, S. Reddy, J. S. Fu, D. Chen, L. Duan, Y. Lei, L. T. Wang, and Z. L. Yao, Asian emissions in 2006 for the NASA INTEX-B mission, Atmos. Chem. Phys., 9, 5131-5153, 2009.

[17] Q. Zhang, D. G. Streets, G. R. Carmichael, K. B. He, H. Huo, A. Kannari, Z. Klimont, I. S. Park, S. Reddy, J. S. Fu, D. Chen, L. Duan, Y. Lei, L. T. Wang, and Z. L. Yao, Asian emissions in 2006 for the NASA INTEX-B mission, Atmos. Chem. Phys., 9, 5131-5153, 2009.

[18] Guidelines for Provincial Emission Inventory, General Office of National Development and Reform Commission, No. 1041, 2011.

[19] General principles for calculation of total production energy consumption, GB/T2589—2008.

[20] Guidelines for Provincial Emission Inventory, General Office of National Development and Reform Commission, No. 1041, 2011.

[21] General principles for calculation of total production energy consumption, GB/T2589—2008.

$$EF_{CO_2} = EF_C \times \mathrm{C} \times a \times \frac{44}{12}$$ Eq. 4

Where:

C is calorific value of coal

EF_{CO2} is CO_2 EF in terms of g/kg

EF_C is EF of carbon

a is oxidation rate of carbon

Therefore, emission saving from idling reduction and emission from heat supply to the heated garages are calculated accordingly and presented in Table 15.

Table 15 Emissions from Idling and Heat Supply to Heated Garages

	NO_x (tonnes)	**PM (tonnes)**	**CO_2 (tonnes)**
Emission saving from idling	53.35	0.25	2471.04
Heat supply	68.13	11.51	18228
Emission reduction	-14.78	-11.26	-15756.96

Note: A minus reduction means emission increase

Although the heated garages are able to reduce the emission from idling, which is an issue that need to be concerned in Harbin, the net emission impact of such idling reduction design are not positive, because the emission from heated garages due to higher emission factor of coal burning would be more than savings from idling reduction. However, from a health perspective, it will benefit the public as the pollution is taken away from the roads, reducing public exposure to air pollution in populated areas. The question is whether proper air pollution control mitigation technologies are in place for the sources that supply the heating. For example, alternative sources of energy for heating will be an approach to achieve net savings of emission from idling reduction.

[22] Guidelines for Provincial Emission Inventory, General Office of National Development and Reform Commission, No. 1041, 2011; General principles for calculation of total production energy consumption, GB/T2589—2008.

3. EMISSION IMPACT ASSESSMENT

The TEEMP calculates the impact of Harbin bus priority corridor project on PM, NO_x and CO_2 emissions by quantifying the construction, operation and traffic impacts of projected bus priority corridor users. The emission savings from such a bus priority corridor project is mainly because: 1) transport mode shift and occupancy factor, for example, in 2034, 16% passengers using Harbin bus priority corridors will be shifted from cars and taxis, which obviously will improve the energy efficiency per trip per person; 2) cleaner fuels, all the new buses introduced in the corridors are CNG buses, which has less CO_2 and PM emission comparing to those using gasoline and diesel; and 3) more stringent emission and fuel standard adopted in future.

Furthermore, idling emission is particularly considered in the Harbin bus priority corridor project, because 10 to 45 minutes under different cold weather conditions are spent to warm up buses in winter before engines can start operating, and when it is extremely cold (below -20°C), staff need to get up twice during night to warm up buses. Therefore, underground heated garages are designed in the Harbin bus priority corridor project, and cold-start problem of buses running in the 3 corridors will be solved. Calculation of such idling emission impact is conducted separately for this assessment, because TEEMP models do not have the idling component designed. Under the idling emission impact assessment, both idling reduction emission savings and emission resulted from municipal heat supply to the heated garages are both calculated, and the result shows that the net emission impact of such idling reduction design is not positive, because the emission from heated garages due to higher emission factor of coal burning would be more than savings from idling reduction. However, from a health perspective, it will benefit the public as the pollution is taken away from the roads, reducing public exposure to air pollution in populated areas.

Table 16 shows the total emissions reduction in 20 years comparing to the business-as-usual scenario, contributed by the transport mode shifting. Two scenarios, direct TEEMP model calculation result without considering idling emission impact, and TEEMP result further calculating idling emission impact, are presented.

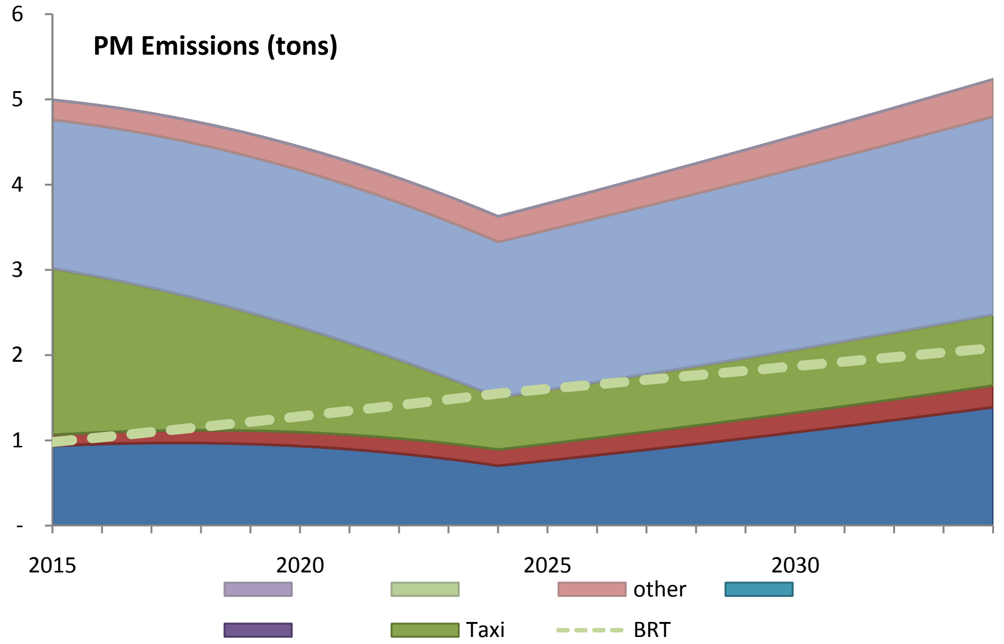
Table 16 TEEMP Results on Emission Savings from Harbin Bus Priority Corridor Project

	Without Idling Reduction	**With Idling Reduction**
PM Reduction (tons)	58.33	43.55
NO_x Reduction (tons)	1,163.46	1,152.20
CO_2 Reduction (tons)	547,639.27	531,882.31

a. The PM savings derived from this project is conservative as emission standards improvement has been underestimated. The technical spilt data (% with various standards) is referred from the roadmap for fuel split and emission standards for China from Transport Roadmap Model developed by ICCT which is released in 2013, because the local city level data is not available. However, Euro V is not included in this road map model while Harbin may move to Euro V in 20 years according to China's newly issued fuel road map and national Action Plan for Air Pollution Prevention and Control. With cleaner fuels and vehicles, more emission reduction can be achieved in Harbin.

   The total PM savings from the bus priority corridor project is 58.33 tons without considering idling emission impact, and comes down to 43.55 tons when idling emission impact is included.

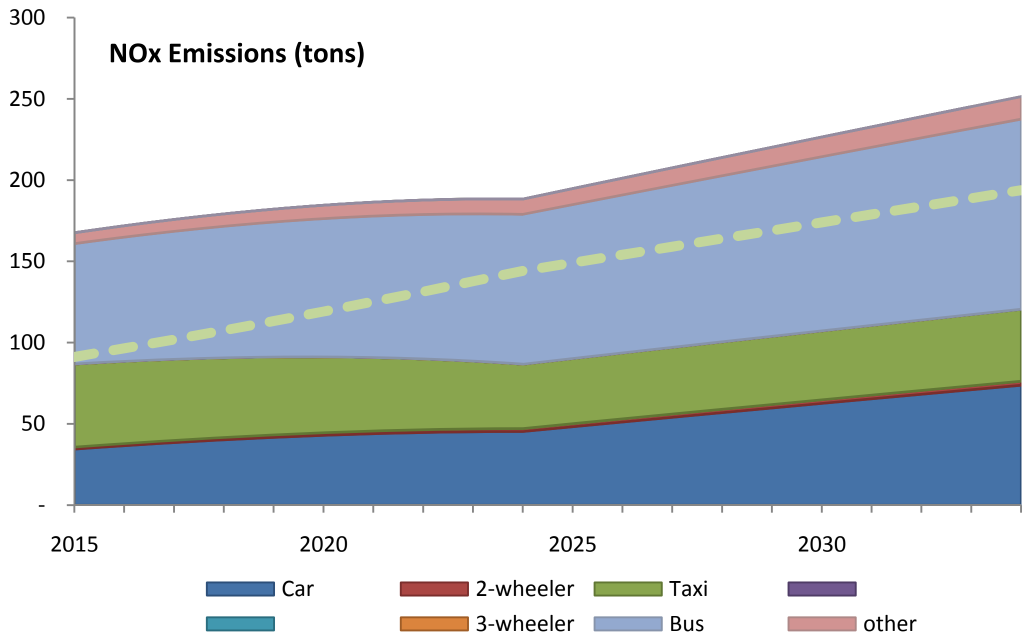
The PM emissions of vehicle types other than bus priority corridor will decrease in the first 10 years resulting from the fleets moving towards more stringent emissions standards, and then rise again due to increasing demand for travel.



Note: Solid area portions refer to modes in a NO BRT Scenario, the impacts of the BRT are depicted by the line

Figure 3 PM Emissions

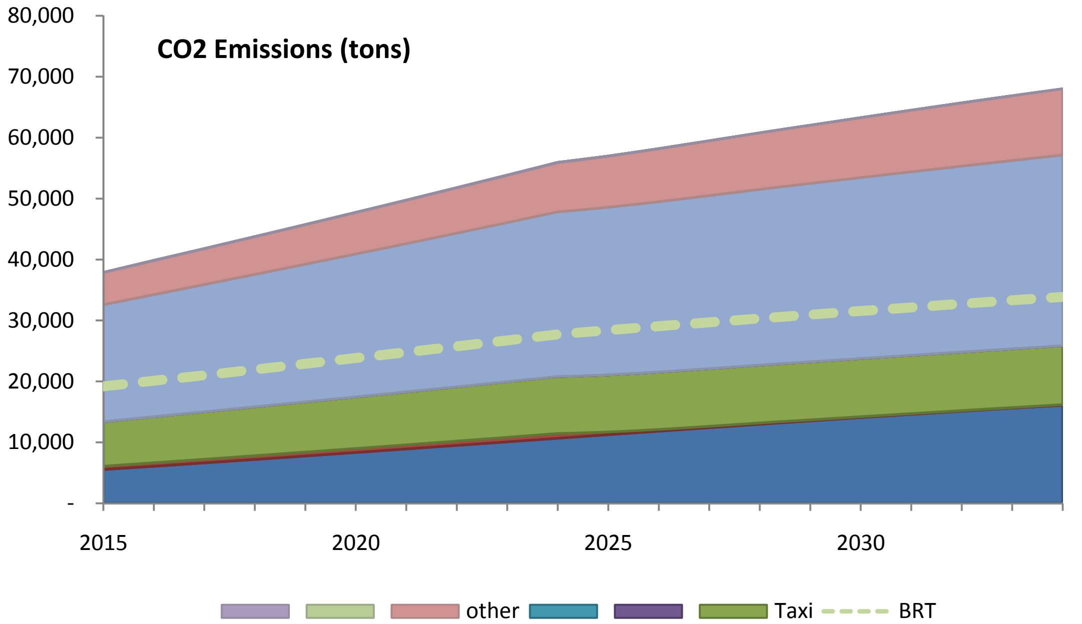
b. The total NO_x savings derived from the bus priority corridor project is 1,163.46 tons without considering idling emission impact. The savings for NO_x is not much as compared to the others (CO_2 and PM). This is because new bus in the corridors moving to CNG results in penalty in terms of NO_x, which has higher emission factor than diesel and gasoline.



Note: Solid area portions refer to modes in a NO BRT Scenario, the impacts of the BRT are depicted by the line

Figure 4 NO_x Emissions

c. The Harbin bus priority corridors will reduce 531,882.31 tons of CO_2 in 20 years with idling emission impact calculated, which is equivalent to taking about 200,000 gasoline cars off the road, which travel 10,000 km per car per year and has an efficiency of 10 km/L. The CO_2 emission impact of idling emission reduction and emission from heated garages is negative, with 15,756.96 tons increase in 20 years. Without considering idling emission impact, CO_2 emission savings of bus priority corridor itself can reach to 547,639.27 tons.



Note: Solid area portions refer to modes in a NO BRT Scenario, the impacts of the BRT are depicted by the line

Figure 5 CO_2 Emissions