The carbon dioxide emission reduction potential in China's road transport sector in 2020

W. Cai, C. Wang, X. Lu & J. Chen

*Department Environmental Science and Engineering,
Tsinghua University, Beijing, People's Republic of China*

Abstract

China is the world's second largest greenhouse gas emitter. Emissions from the road transport sector represent one of the fastest growing carbon dioxide (CO₂) sources in China. Based on previous research of projections about China's future vehicle ownership and the CO₂ emission in the road transport sector, this paper reviews all recent environmental policies in the automobile industry and employs scenario analysis to estimate different emission inventories in different development strategies. The new policy scenario considered all possible mitigation options available in the road transport sector from a bottom-up perspective and examined the fuel efficiency improvement effects and costs of these mitigation options – vehicle technology improvement, a Bus Rapid Transit system, and a fuel switch, through which the carbon dioxide emission reduction potential was estimated. Not only does this paper indicate that a large emission reduction potential exists in China's road transportation sector, but it infers that vehicle technology improvement, especially engine technology, is likely to be the most effective means to meet emission reduction targets. This paper concludes by identifying key barriers to implement those options in China and induces China's demand, mainly in technical, financial and institutional aspects, for national capacity building and international aids, to achieve emission reduction goals.

Keywords: emission reduction potential; road transport; scenario analysis; bottom-up approach.

1 Introduction

In recent years, great concerns have been expressed towards the concentration of one major representative of greenhouse gases (GHG) – carbon dioxide (CO₂). Plenty of countries are playing an active role in reducing CO₂ emissions, through native mitigation and adaptation policies, and through international and intergovernmental mechanisms such as the United Nations Framework Convention on Climate Change (UNFCCC). Among all sectors that emit CO₂, the transport sector is the fastest growing source, representing from 22 percent to 24 percent of global GHG emissions from fossil fuel sources, second only to the industrial sector (Wright [1]). However, few effective remedies have been developed to curb fuel consumption and GHG emissions from the transport sector. Yet the good news is that more and more researchers have started to analyze the CO₂ emission reduction from transport sector, by bottom-up and top-down approaches (Michaelis [2], Difiglio [3], Zachariadis [4], Simões et al. [5], etc).

In China, the share of CO₂ emission from the transport sector is comparatively lower, which is 6% in 1990 and 8% in 2000, and is projected to increase to 12% in 2020 (IEA [6]). However, the motorization in Chinese society has just come (Baumert and Winkler [7]). In 2004, there were only 27 million privately owned motor vehicles in China (Brown [8]), with most of them concentrated in large Chinese cities. The car ownership was approximately 9 cars per 1,000 people, far below the global average (He et al. [9]). By comparison, there are over 700 cars (including personal vans, light trucks, and SUVs) per 1,000 people in US, 400 in Japan, 350-500 in Europe, and 150-200 in middle-income countries like Mexico, Brazil, and Korea. It is projected that the vehicle population will triple in 2020 compared to 2000 (Huo [10]). Considering the development path of transport sector in developed countries, there is little doubt that road transport sector will become dominant in China's emission inventory in the near future. As the second largest emitter of CO₂ in the world today, China will have and has had a larger and larger pressure from emission reduction. In order to analyze the potential of emission reduction in China's transport sector and to point out the most effective way to achieve emission reduction, this study identified factors that determine CO₂ emission in the road transport sector and developed three scenarios (a Business-as-usual scenario, a recent policy scenario and a new policy scenario) based on government policies, plans and strategies.

Some other Chinese researchers have estimated current road transport energy use and CO₂ emission (Wang [11], DRC and DESE [12], Ke and Shang [13]). And some has estimated the emission reduction potential in total transportation sector (Zhou [14]). Yet this study explores the focus on the road transport sector, and through the deduction of costs and fuel efficiency effects of several specific mitigation packages, to estimate its CO₂ emission reduction potential, which follows a typical bottom-up approach.

2 Current status and future projection of the road transport sector in China

To describe the properties of the road transport sector with respect to CO₂ emissions, at least three factors need to be clarified – vehicle population (VP), annual vehicle mileage travelled (VMT) and fuel efficiency (FE).

The Chinese statistical protocol classifies motor vehicles into trucks, buses and cars. Furthermore, trucks are classified into heavy-duty trucks (HDTs), medium-duty trucks (MDTs), light-duty trucks (LDTs), and mini trucks (MTs), and buses are classified into heavy-duty buses (HDBs), medium-duty buses (MDBs), light-duty buses (LDBs), and mini buses (MBs). Cars, trucks and buses can be further classified into gasoline and diesel vehicles, expressed as G and D, respectively. For instance, HDT-D represents heavy-duty diesel trucks. In this study, motorcycles are also included as one vehicle type.

2.1 Current status

As the baseline of the following scenario analysis is year 2000, the data in the current status will all be in 2000. Due to the lack of available statistic data and information in China's road transport sector, data listed in this part are based primarily on He et al. [9] and Huo [10]. For information related to projection methodology, please refer to the two references as well.

Table 1: Current status of FE (km/L) in 2000.

	HDT-G	HDT-D	MDT-G	MDT-D	LDT-G	LDT-D	MT-G	MT-D	Car-G	Car-D
New vehicles	3	4.42	3.98	5.71	7.87	8.7	15.38	18	14.71	20
On-road performance of fleet wide	2.25	3.32	2.99	4.28	5.9	6.53	11.54	13.5	11.03	15
	HDB-G	HDB-D	MDB-G	MDB-D	LDB-G	LDB-D	MB-G	MB-D	Motorcycle	
New vehicles	2.94	4.03	3.57	4.21	10.03	11.76	15.87	19	49.02	
On-road performance of fleet wide	2.21	3.02	2.68	3.16	7.52	8.82	11.9	14.25	36.77	

VP: In 2000, there were 15.53 million units of vehicles in China and 31.5 million motorcycles. Among the 15.53 million, 7.11 were trucks, 3.57 were buses and the other 4.85 were cars. LDT took up the largest portion in trucks. And MB took the same position in buses. Most light duty vehicles (LDVs) were using gasoline as their fuel. Refer to table 2 for more information.

VMT: In 2000, HDT had the longest VMT, which was 67.4 thousand km/yr. Cars travelled 26.4 thousand km/yr. Refer to table 2 for more information.

FE: It will vary between FE performance of new vehicle and the actual on-road FE performance of fleet wide. An adjustment factor α was multiplied to the

new vehicle FE to transform to the on-road FE. Refer to table 1 for more information. According to He [9], the average α value is 0.75.

2.2 Future projection

VP and VMT: Projection of these two indicators till 2020 is shown in table 2. For more information on the underlying methodology and process, please refer to He et al. [9]. VP is keeping a fast-growing tendency and VMT, is falling down due to the continuously increasing VP and a comparatively limited need for passenger and freight transportation.

FE: The future projection of FE will be reflected in the scenario design.

Table 2: Current status and future projection of VP, VMT from 2000-2020.

	VP (million units)						VMT (thousand kilometers)				
	2000	2005	2010	2015	2020		2000	2005	2010	2015	2020
HDT-G	0.02	0.02	0.02	0.03	0.02		67.40	50.00	50.00	50.00	50.00
HDT-D	0.40	0.87	1.87	2.89	3.62		67.40	50.00	50.00	50.00	50.00
MDT-G	0.75	0.46	0.34	0.28	0.21		25.00	24.00	24.00	24.00	24.00
MDT-D	1.39	1.32	0.89	0.66	0.55		25.00	24.00	24.00	24.00	24.00
LDT-G	1.23	1.22	1.60	1.97	2.34		20.90	19.50	18.00	16.50	15.00
LDT-D	2.01	1.91	2.79	3.72	4.67		20.90	19.50	18.00	16.50	15.00
MT-G	1.39	1.15	1.39	1.42	1.50		43.20	35.55	30.37	25.18	20.00
MT-D	0.001	0.01	0.03	0.07	0.10		43.20	35.55	30.37	25.18	20.00
HDB-G	0.003	0.01	0.01	0.01	0.01		52.00	51.05	52.37	53.68	55.00
HDB-D	0.05	0.09	0.15	0.21	0.29		52.00	51.05	52.37	53.68	55.00
MDB-G	0.13	0.20	0.29	0.43	0.67		52.00	46.84	42.89	38.95	35.00
MDB-D	0.15	0.25	0.41	0.64	1.11		52.00	46.84	42.89	38.95	35.00
LDB-G	1.31	1.94	2.63	3.54	4.88		34.00	32.11	29.74	27.37	25.00
LDB-D	0.55	0.86	1.34	1.93	2.90		34.00	32.11	29.74	27.37	25.00
MB-G	1.96	3.97	7.12	10.36	14.76		35.00	32.11	29.74	27.37	25.00
MB-D	0.00	0.04	0.19	0.52	1.14		35.00	32.11	29.74	27.37	25.00
Car-G	4.40	10.06	16.97	26.46	41.70		26.40	24.00	21.00	18.00	15.00
Car-D	0.00	0.26	0.89	2.15	4.63		26.40	24.00	21.00	18.00	15.00
Motorcycle	37.72	89.56	133.27	158.12	175.62		9.00	9.00	9.00	9.00	9.00

3 Scenario design

Scenario design in the session is based on the literature research and analysis of past environmental policies with relation to the road transport sector (the Ministry of Transportation [15], the National Development and Reform Commission (NDRC) [16], the General Administration of Quality Supervision and the Inspection and Quarantine of the People's Republic of China [17]).

In this study, three scenarios are employed, the reference baseline scenario, the recent policy scenario and the new policy scenario.

The reference baseline scenario is a conservative projection of the future of the road transport sector. The baseline of this study is year 2000, so the scenario assumes the FE level of new vehicles (NFE) will remain at the current FE level.

In the recent policy scenario, we will evaluate projected emissions using combination of measures and policies in place before the end of 2005, especially the implementation of fuel efficiency limits of the targeted fleets. The policy takes more consideration for environmental protection issues. And it is assumed that measure and policies before the end of 2005 would be 100% implemented.

In the new policy scenario (mitigation scenario), sustainable development is being mostly emphasized, and climate change issues have been taking into consideration. Here we assume a relative radical phase that China invests a lot to adopt more advanced technologies to reduce energy consumption and GHG emissions, with less consideration of financing or technical barriers.

Several special mitigation options aiming at CO₂ emission reduction are input in this new policy scenario. All possible mitigation options could be categorized into three groups: vehicle related options, road related options and fuel related options. Vehicle related options include improving engine technologies, transmission technologies, vehicle technologies (rear to front) and engine-transmission-vehicle technologies. (For more detailed information on each type of technology, please refer to Huo [10].) Road related options include urban planning, Bus Rapid Transit (BRT), improving road conditions, etc. Fuel related options include renewable fuels and more clean fuels substitution.

Table 3: List of mitigation options.

		FE improve ment (%)	Cost (USD)
1 Engine technology	Multi-valve, overhead camshaft	39.0%	1694
	Variable valve lift and timing		
	Low-friction lubricants		
	Components		
	Roller cylinder (rocker)		
	Engine accessory improvement		
	Variable compression ratio engine		
	HEV or Direct injection gasoline/diesel engine		
2 Transmission technologies	Automatic Transmission with aggressive shift logic	6.8%	430.5
	Change the transmission		
3 Vehicle technologies (rear to front)	Aerodynamic improvement	8.95%	816.2
	Low-resistance tires		
	42 volt electricity system		
	Safety enhancing weight reductions		
4 Engine-Transmission-Vehicle technologies		1.48%	120.9
5 BRT		—	—
6 Fuel Switch		—	—

Selection criteria for these mitigation options mainly are the net costs (including R&D cost, infrastructure cost, management and operational cost, human resource cost, and oil saving costing and some other co-benefits, if data is available), fuel efficiency improvement performance or carbon dioxide

emissions abatement performance, and practicality (whether it could align with the current development status of the Chinese society).

Based on previous researches and analysis (Gallagher [18], Huo [10], Xu [19], Jiang [20]), the final included 6 packages of technology and option are shown in table 3. However, all the cost data in the vehicle technology part reflects only the operational cost. The cost for R&D, technology trade, managerial cost and etc are not included, because there is little research on this area and it is far too complex to estimate. Wright and Fulton [21] have referred the FE improvement effects of BRT and fuel switch and the corresponding costs. Combining the previous research with the current reality of China, it is estimated that the incremental cost for implementing BRT is 4.64 \$/metric ton CO₂ in 2020 and the total emission reduction achieved by BRT in 2020 could reach 34.4 million tons. And in 2020, costs for each metric ton CO₂ emission reduction from fuel switch would be 326.4 USD, and could reach an emission reduction amount of 45.8 million tons.

4 Results

To deduce the fuel consumption (FC) and Emission of CO₂, equation (1) and (2) are used:

$$FC_j = \sum_i (VP_{i,j} \times VMT_{i,j} \times FE_{i,j}^{-1} \times FD_j) \quad (1)$$

$$E_{CO_2} = \sum_j FC_j \times \alpha_j \times \frac{44}{12} \quad (2)$$

where FC_j represents fuel consumption (million tons), FD_j the fuel density, E_{CO₂} the total CO₂ emission, α_j the percent of carbon in fuel, i represents vehicle type, j represents fuel type (gasoline & diesel). We assume density and the percent of carbon in fuel is constant. The density of vehicle gasoline is 0.732 kg/L, and the percent of carbon in it is 85.5%; the density of vehicle diesel is 0.875 kg/L, and the percent of carbon in it is 87%.

4.1 The current fuel consumption and CO₂ emission (in 2000)

By inputting data from current status, we could deduce the current fuel consumption and CO₂ emission in 2000, which are respectively 61.5 million tons and 194.0 million tons.

4.2 Oil consumption and CO₂ emission in scenarios

Figures 1 and 2 have compared the oil consumption and CO₂ emission in three scenarios, from 2000 to 2020.

Generally speaking, CO₂ emission in transport sector in China till 2020 will keep growing, even under new policy scenario. However, after the implementation of mitigation options, the emission reduction of CO₂ is quite obvious.

In reference baseline scenario where no consideration had been given to environmental protection and climate change issues, the CO₂ emission in 2020 would reach 664 million tons, which is 3.4 times of the emission in 2000. Yet in recent policy scenario where limitation on fuel economy has released, the CO₂ emission in 2020 would be 595 million tons, achieving a reduction volume of 69 million tons. Conservatively speaking, as the limitation on fuel economy had already been released, the 69 million tons of CO₂ could be considered as the minimum reduction potential in China's road transport sector in 2020. In the new policy scenario where six mitigation packages are utilized, the emission in new policy scenario is 380 million tons, only 2 times of the emission in 2000. A large emission reduction has been achieved – nearly 284 million tons, which could be considered as the optimistic CO₂ emission reduction potential in China in 2020.

Figure 1: Comparison of different scenarios in total oil consumption.

Figure 2: Comparison of different scenarios in total CO₂ emission.

4.3 Costs and emission reduction effects of each mitigation option

Table 4 summarized the costs and emission reduction effects of each mitigation option. However, the cost information for these technologies should be read in another way, because as mentioned before, in all calculation, we had only induced the operational cost of those technologies. However, these data could still simulate the situation when technologies are just by our side and the situation when we can immediately utilize them in a pleasant outer environment, through the efforts of asking for international technological or financial aid.

Table 4: Cost of mitigation options and relevant emission reduction at 2020.

Mitigation Option	Cost Effectiveness (\$/metric ton CO ₂ e)	Total Emission Reduction (million metric tons CO ₂ e)
Engine Technology	-122.4	153.1
Transmission Technology	-114.2	26.6
Engine-Transmission-Vehicle technologies	-101.1	5.79
Vehicle Technologies (rear-to-front)	-94.4	35.2
Bus Rapid Transit	4.64	27.3
Fuel Substitution	326.4	36.4

4.4 Contribution of each mitigation option to the emission reduction potential

Six mitigation options have been utilized in new policy scenario to affect the fuel efficiency. The main attributor to the 284 million tons of emission reduction goes to Engine Technologies. 53.9% emission reduction is achieved by it, followed by fuel switch 12.8%, vehicle technology (rear to front) 12.4%, BRT 9.6%, transmission technologies 9.37% and engine-transmission-vehicle technologies 2.04%.

5 Conclusion and discussion

Concluding from all the analysis above, a huge emission reduction potential exists in the current road transport sector in China. In 2020, the amount of CO₂ emission could reach as low as 380 million tons if all mitigation options in the new policy scenario are well implemented. The emission reduction potential ranged from 69-284 million tons under different scenarios, which is about 10~40% of the total emission in this sector.

Vehicle-related technologies are surely the wisest choice to mitigate GHG emission in China. They could achieve nearly 78% of the total emission reduction in 2020. Among the vehicle-related technologies, the engine technologies are the most significant contributor. It takes up more than 50% of the total reduction amount.

However, we should not be too optimistic towards the huge emission reduction potential, because there are a lot of barriers to overcome on our road to achieve this reduction potential. One of the key barriers is the unconsciousness of climate change issues in related governors and public. China is quite lacking of laws and policies to support implementing those mitigation options. Another key barrier is the cost of vehicle-related technologies. It is widely recognized that the current vehicle technology in China is lagging behind most of the advanced countries. Although technologies listed in the new policy scenario are possible to be utilized in China, yet we still have to take full consideration on the astonishing expenses for technology transfer, research and development, the costs to construct suitable factories and product lines, to train necessary labor and technicians, to maintain the right working order and to manage and operate. Last but not least, barrier also exists in the capacity building aspect. It is in urgent need that government could have a strong management power over the CO₂ emission in urban transport sector, and more and more researches could be launched to identify emission reduction keystone and possible pathway to achieve emission reduction targets.

Policies which can promote advanced technology application include direct government regulation to mandate (or allow) the adoption of these technologies, government-run voluntary assistance program to provide information and training to production companies, direct subsidy from government on investment, R&D, etc, demand side management such as lower down the sales price of advanced vehicles or rebates for consumer purchases, releasing emission standards and fuel efficiency standards, and making local air pollution

regulations and having control on energy intensity, emission intensity, national emission growth limits, emissions cap and trade, carbon tax and energy taxes, etc. Besides these, it is also appropriate to start capacity building, such as setting up right political environment or market and training the right people (including governors and researchers), to meet the requirements of those mitigation options. More importantly, international financial and technical aids such as loans, technology transfer and joint collaboration would help China overcome financial and technical barriers in an effective and efficient way.

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