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Fuel consumption and life cycle GHG emissions by China's on-road trucks: Future trends through 2050 and evaluation of mitigation measures

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ABSTRACT

We established a bottom-up model to deliver the future trends of fuel consumption and life cycle greenhouse gas (GHG) emissions by China's on-road trucks. The mitigation measures of mileage utilization rate (MUR) improvement, fuel consumption rate (FCR) improvement, and penetration of liquefied natural gas (LNG) fueled trucks were evaluated. With no mitigation measures implemented, in the year 2050, the total fuel consumption and life cycle GHG emissions by China's on-road trucks were projected to reach 498 million toe and 2125 million tons, respectively, approximately 5.2 times the level in 2010. If the MUR of trucks in China is increased from the current status as those of the developed countries, a 13% reduction of total fuel consumption can be achieved after 2020. If the FCR of trucks is reduced by 10% in 2011, 2016, 2021, and 2026, a 30% reduction of total fuel consumption can be achieved after 2030. Moreover, if the share of LNG fueled trucks in all newly registered semi-trailer towing trucks and heavy-duty trucks is increased to 20% in 2030, an estimate of 7.9% and 10.9% of the total diesel consumption by trucks will be replaced by LNG in 2030 and 2050, respectively.

1. Introduction

Over the past three decades, China's domestic FTV has experienced rapid growth, increasing from 1202 billion t km in 1980 to 12,213 billion t km in 2009, with an annual growth rate of 8.3% (National Bureau of Statistics of PRC, 2010). With the growth of road freight transport demand, total truck registration in China increased from 1.3 million in 1980 to 13.7 million in 2009 (National Bureau of Statistics of PRC, 2010). The operating trucks (trucks dedicated to profitable freight transport) created 3719 billion t km of FTV in 2009, accounting for about 30% of total domestic FTV (National Bureau of Statistics of PRC, 2010).[1] Truck fleet is the main consumer of diesel in China. In 2007, an estimated 63.7 million tons of diesel were consumed by China's on-road vehicles (mostly by trucks), accounting for over half of the total domestic diesel consumption (National Development and Reform Commission of PRC, 2009).[2] Numerous studies have been conducted to project fuel consumption and GHG emissions by vehicles in China (Hao et al., 2011a, 2011b; He et al., 2005; Huo et al., 2007; Ou et al., 2010b; Wang et al., 2007; Yan and Crookes, 2009). Huo et al. established a bottom-up model to simulate the growth of fuel consumption and GHG emissions by all highway vehicles in China. They projected that under mid vehicle growth scenario, the total truck registration in China would reach 28 million, 52 million, and 103 million in 2020, 2030, and 2050, respectively. Accordingly, under mid vehicle growth and moderate fuel economy scenario, the total fuel consumption by trucks would reach 129 million, 221 million, and 503 million tons in 2020, 2030, and 2050, respectively. The aforementioned study also demonstrated the significance and urgency of implementing fuel economy standards for vehicles in China. Studies mentioned above are generally based on a unified model for all highway vehicles including passenger vehicles, buses, and trucks. In the current study, the scope focused on the modeling of fuel consumption and GHG emissions by trucks. There are three major improvements in the truck-specialized model compared with past models: (1) in the past models, vehicle registrations and APDT were projected individually. In fact, these

Abbreviations: APDT, Annual per-vehicle distance traveled; DF, Diesel fueled; FCR, Fuel consumption rate; FLT, Four-wheel low-speed trucks; FTD, Freight transport density; FTV, Freight transport volume; GF, Gasoline fueled; GHG, Greenhouse gas; GVW, Gross vehicle weight; HDT, Heavy-duty trucks; LDT, Light-duty trucks; LNG, Liquefied natural gas; MDT, Medium-duty trucks; MT, Mini trucks; Mtoe, Million tons of oil equivalent; MUR, Mileage utilization rate; STT, Semi-trailer towing trucks; TLT, Three-wheel low-speed trucks

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[1] The rest of domestic FTV was shared by railway (20.7%), waterway (47.1%), aviation (0.1%), and pipeline (1.7%).

[2] The rest of the diesel consumption was shared by agricultural machinery, rail transport, waterway transport, fishery, power generation, building construction, mining, commercial use, and civil use.

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two factors are coupled for trucks because the increase of APDT may result in the decrease of truck registration under the same demand for freight transport. In this study, truck registration is paired with APDT by employing FTV, which is defined as the product of truck registration, APDT, and per-truck volume of freight loaded. (2) In the past models, the total truck registration was projected first and registrations of each truck classification were divided subsequently based on experience. However, in the current work, the future trends of each truck classification were projected individually by investigating their own characteristics. (3) In the past models, the FCRs of trucks were estimated without considering whether they are loaded, which may cause discrepancy because the FCRs of loaded trucks and empty trucks are entirely different. In this study, different FCRs were employed for loaded trucks and empty trucks. Consequently, the APDT was divided into two classifications: loaded distance traveled and empty distance traveled by employing MUR (i.e., the percentage of loaded distance traveled in total distance traveled). Hence, the proposed model can simulate the effect of increasing MUR on reduction of fuel consumption and GHG emissions. Such simulation can be highly beneficial for China because the current MUR of trucks in China is much lower than those of developed countries (CATS, 2008). Based on the improved truck-specialized model, the past trends (2000–2010) were estimated. Future trends (2011–2050) of fuel consumption and life cycle GHG emissions by China's on-road trucks were also projected. The effects of MUR improvement, FCR improvement, and penetration of LNG fueled trucks on fuel conservation and GHG emissions reduction were evaluated.

2. Methodology

In this study, we established a bottom–up model to deliver the fuel consumption and life cycle GHG emissions by China's on-road trucks. The structure of the model is illustrated in Fig. 1.

For the data from previous years to 2010, the number of newly registered trucks, number of total registered trucks, and FTVs by trucks (in t km) were estimated using Eqs. (1)–(4).

$$NR_{i,k,m} = PR_{i,k,m} + IM_{i,k,m} - EX_{i,k,m} \quad (1)$$

$$TR_{i,k} = \sum_{m} \sum_{1980 \le j \le i} NR_{j,k,m} \cdot SR_{j,i-j,k} \quad (2)$$

$$IFTV_{i,k} = TR_{i,k} \cdot APDT_{i,k} \cdot PFL_{i,k} \quad (3)$$

$$FTV_{i,k} = (IFTV_{i-1,k} + IFTV_{i,k})/2 \quad (4)$$

where $NR_{i,k,m}$ is the number of classification k trucks using type m fuel newly registered in year i; $PR_{i,k,m}$ is the number of classification k trucks using type m fuel produced in year i; $IM_{i,k,m}$ is the number of classification k trucks using type m fuel imported in year i; $EX_{i,k,m}$ is the number of classification k trucks using type m fuel exported in year i; $TR_{i,k}$ is the number of total registered classification k trucks in year i; $SR_{j,i-j,k}$ is the survival ratio of classification k trucks newly registered in year j at age $i-j$; $IFTV_{i,k}$ is the indicated FTV by classification k trucks in year i; $APDT_{i,k}$ is the APDT of classification k trucks in year i; $PFL_{i,k}$ is the per-truck volume of freight loaded of classification k trucks in year i; and $FTV_{i,k}$ is the FTV by classification k trucks in year i (in ton-km).

For the years after 2010, the FTVs by trucks were projected based on the past estimations. The details of projection are introduced in Section 4.1. Based on the projected FTVs, the number of newly registered trucks and total registered trucks after 2010 were calculated using Eqs. (5) and (6).

$$TR_{i,k} = IFTV_{i,k}/(APDT_{i,k} \cdot PFL_{i,k}) \quad (5)$$

$$NR_{i,k,m} = \left(TR_{i,k} - \sum_{m} \sum_{1980 \le j \le i-1} NR_{j,k,m} \cdot SR_{j,i-j,k} \right) \cdot SH_{i,k}^{i,k,m} \quad (6)$$

where $SH_{i,k}^{i,k,m}$ is the share of classification k trucks using type m fuel in all newly registered classification k trucks in year i. The total fuel consumption and life cycle GHG emissions by

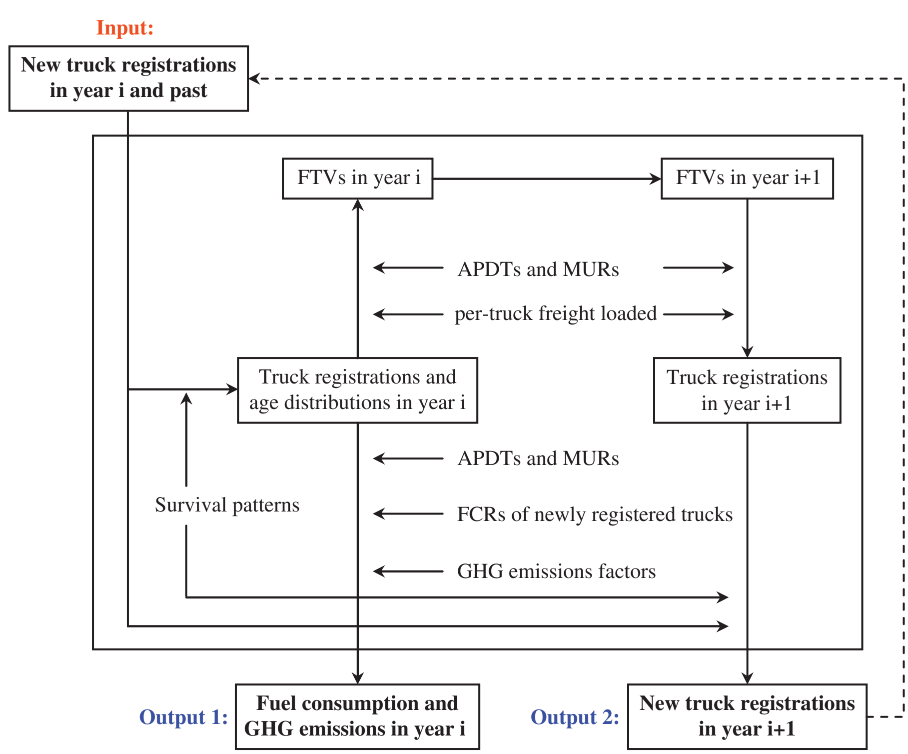

Fig. 1. Diagram of model structure.