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# Study on whole-life cycle automotive manufacturing industry CO2 emission accounting method and Application in Chongqing

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**Abstract** Low carbon economy has become a worldwide trend, many countries are seeking low carbon means to achieve environmentally- friendly economy growth. However, various Greenhouse gases species in different industries, as well as various detection technology development levels in different countries lead to different carbon emissions accounting results eventually. So the accurate micro-level accounting on carbon dioxide emission is difficult to achieve while in the mean time, it is the basis for subsequent scenario analysis, which plays a crucial role in carbon pricing and carbon credits market promotion. That's why the regional carbon dioxide emission accounting is a hot issue in low-carbon economy. Nowadays, automotive manufacturing industry has become a big fuel consumer in China and an important source of air pollution. So an accounting method focused on carbon dioxide emission in Chinese automotive industry is essential and practical significant. This paper proposed a whole-life cycle carbon emissions methodology to account carbon dioxide emission in Chinese automotive manufacturing industry, which is based on GREET and MOBILE model. And then the feasibility is verified through application in the automotive industry in Chongqing, China.

**Keywords** automotive manufacturing industry, carbon dioxide emissions accounting, GREET model, MOBILE model, whole-life cycle

## 1 INTRODUCTION

Developing low carbon economy has become a worldwide trend, many countries are seeking the low carbon way to build environmental friendly society as well as achieve economy growth (Zhang et al., 2009). Yiming Wei said 63.09% to 72.96% of carbon emission comes from electric power, industry (not including cement) and traffic & transportation (Wei et al., 2008). Nowadays automotive manufacturing industry, which belongs to traffic & transportation, has turned to be a large fuel consumer and an important source of air pollution. So how to calculate its carbon emission correctly and effectively has become a research focus. What's more, the study on accounting GHGs emissions in automotive manufacturing industry has practical significance for China, which is a super country in manufacture industry.

Recently, researches on automotive carbon emission calculation mostly focus on GHGs emissions of automotive operation process in transportation department, such as retained automotives in given regions of certain years of which the most popular ones are GREET model and MOBILE model and so on( Wang, 2002). GREET model assesses the energy utilization and emission influence during

whole-life cycle of alternative fuels and advanced vehicle technologies.

In terms of energy utilization, GREET model consists of three different levels: overall energy, fossil energy and petroleum based energy. While for emission influence, GREET model concludes three main GHGs (CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O) and five standard emissions (VOC, CO, NO<sub>x</sub>, PM10, Sox)(ANL; Huang, 2003). MOBILE model series are a kind of macro-level mathematics model to calculate vehicle emission factors with consideration of influence comes from elements such as vehicle's age distribution, mileage, emission factor of new vehicles, degradation rate, speed, inspection / maintenance system, environmental conditions, road conditions, operation conditions of vehicles and fuel features and so on(Huang, 2003)

These two models are both widely used in macro-level vehicle emission calculation. GREET model calculates the emission in whole-life cycle of vehicles, from raw materials producing to automotive manufacturing and finally to fuel consumption of automotive operation such series of carbon emissions "from cradle to tomb". This carbon emission calculation method needs a systematical assessment of vehicles' whole-life cycle, to assure reflection of the actual carbon emission of automotive industry. While, in fact, various development levels of automotive manufacturing industry in different areas and different difficulty levels when accessing data of raw materials melting & producing process and automotive manufacturing process, make it difficult to applied. In other aspect, most of the discussions focused on calculation of vehicles operation GHGs emissions of transportation department in national and regional level. However, calculation from the view of regional level automotive manufacturing industry is rarely discussed. To sum up, in terms of Chinese automotive manufacturing industry, how to build an accurate carbon emission assessment method is an urgent problem needs to be solved. So, this paper proposes a whole-life cycle model to calculate carbon emissions of regional automotive manufacturing industry. This model calculates regional automotive manufacturing industry GHGs emissions from whole-life cycle view: from raw material melting and producing to automotive manufacturing and finally to automotive operation and recycle. The research analyzes the fundamental factors of GHGs emission from the perspective of automobile manufacturers who are the origin of emissions, and then result of the research can provide decision support for government to set GHGs emission targets and make relevant policies.

## **2 Problem Description**

How to calculate carbon emission of automotive manufacturing industry in regional level. This paper proposed a whole-life cycle model of calculating carbon emissions of regional automotive manufacturing industry on the basis of GREET and MOBILE model. This model calculates automotive manufacturing industry carbon emission of whole-life cycle from raw material melting & producing to automotive manufacturing and finally to automotive operation and recycle from the perspective of automobile manufacturers.

## **3 Methodology & Model**

### **3.1 Regional Automotive Manufacturing Industry Whole-life Cycle Carbon Emission Calculation Technology Roadmap**

Regional automotive manufacturing carbon emission calculation of whole-life cycle from raw material melting and producing to automotive manufacturing and finally to automotive operation and recycle

process from the perspective of automobile manufacturers. These three processes take material structure, product structure and fuel structure of substance flow as main body of calculation, and then calculate GHGs emission with those emission factors as shown in Fig.1.

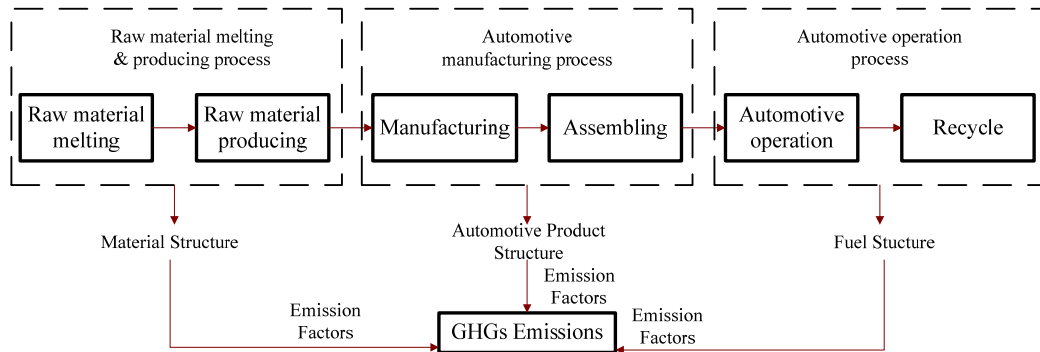


Fig.1 Regional Automotive Manufacturing Industry Whole-life Cycle Carbon Emission Calculation Model technology roadmap

### 3.2 Automotive operation process carbon emission calculation model

The principle of the three part of the Regional Automotive Manufacturing Industry Whole-life Cycle Carbon Emission Calculation Model are the same, they only varies in concrete structure, statistics and emission factors. Here we only talked about the principle of automotive operation process carbon emission calculation model in detail.

#### 3.2.1 Overall description of automotive operation process carbon emission calculation model

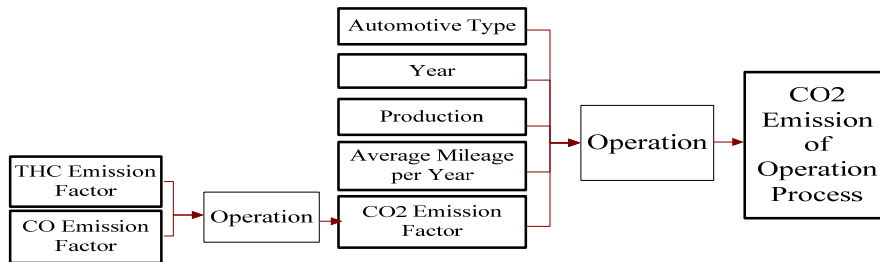


Fig.2 Automotive operation process carbon emission calculation model

As shown in Fig. 2, there are two steps in automotive operation process carbon emission calculation:

Step 1: Calculation of  $CO_2$  emission factors

$CO_2$  emission factors are calculated by use of THC and CO emission factors and fuel consumption referring principles of MOBILE model.

Equation of calculating  $CO_2$  emission factors : (Li, 2003)

$$CO_2^m = [(C_{fuel} - f_{THC}) \times 0.87 - f_{CO} \times 0.42] \div 0.273 \quad (1)$$

$f_{THC}$  : THC (total hydrocarbon) emission factors (g/km) ;

$f_{CO}$  : CO (carbon monoxide) emission factors (g/km) ;

$C_{fuel}$  : fuel consumption (g/km) ;

0.87 : Carbon content of THC (total hydrocarbon);

0.42 : Carbon content of CO (carbon monoxide);

0.273 : Carbon content of CO<sub>2</sub> (carbon dioxide);

Step 2: Calculation of carbon emission of automotive operation process

With CO<sub>2</sub> emission factor, we put it into the model with other factors such as automotive types, year, product structure, average mileage per year and get carbon emission of automotive operation process.

Equation of calculating CO<sub>2</sub> emission of automotive operation process: (Li, 2003)

$$EQ_p = \sum (P_j \times M_j \times CO_2^m) \quad (2)$$

$j$  : Automotive type;

$P_j$  : Production (ten thousand vehicles) ;

$M_j$  : Average mileage per year of each vehicle (ten thousand km) ;

$CO_2^m$  : CO<sub>2</sub> (carbon dioxide) emission factors;

## 4 Case Analysis

### 4.1 Statistics Source

Chongqing holds a dominant position in Chinese Automotive and motorcycle manufacturing industry, of which Changan Group Co. Ltd. produced second most vehicles nationally in 2009 and Chongqing's motorcycle industry produced most motorcycles nationally all along. Automotive manufacturing industry is the primary pillar industry in Chongqing and develops very well during "the Tenth five year plan" from year 2000 to 2005. Automotive production developed at the average rate of 25%, and sales value developed at the average rate of 28.9% in this period. By the end of 2005, Chongqing has 24 automotive corporations including Changan, Qingling, Chongqi, Tiema and other famous corporations and groups, and possess 55.824 billion RMB assets.

Here we take a case study to verify the regional automotive manufacturing industry whole-life cycle carbon emission calculating model). The case is about the CO<sub>2</sub> emission of operation process of vehicles that are manufactured by Chongqing automotive manufacturers in year 2005. Our data sources include China's automotive industry yearbook, Chongqing's governmental report and Chongqing's environment bureau etc.

### 4.2 Calculation Process

#### 4.2.1 Calculation of CO<sub>2</sub> emission factors

Step 1: CO and THC emission factors

We take Chongqing's automotive emission factors measured on the spot in 2004 as shown in Table 1(Guo, 2009).

Table 1 THC and CO emission factors of Chongqing in 2004

Emission	MINI	Saloon	Light	Light	Medium	Heavy	Motorcycle
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Factors(EF)			gasoline	diesel	diesel	diesel	
CO EF (g/km)	25.3	31.93	53	3.8	51.7	8.52	14.4
THC EF (g/km)	5.7	3.08	7.55	0.94	9.5	5.73	2

Step 2: Fuel consumption in a hundred kilometers

Equation of calculating each types of vehicle's fuel consumption in a hundred kilometers (L/100 km):

$$cfuel(L/100km) = \sum Qj' * c \quad (3)$$

cfuel(L/100km): Fuel consumption in a hundred kilometers (L/100 km);

j': Model of each type;

Qj': Production of different models in 2005;

c: Fuel consumption in a hundred kilometers (L/100 km);

Table 2 shows the fuel consumption in a hundred kilometers of each type of automotives manufactured in Chongqing in 2005(CAIY, 2006)

Table 2 Fuel consumption in a hundred kilometers of Chongqing in 2005

Fuel consumption(FC)	MI NI	S aloon n	Light gasoline	Light diesel	Medium diesel	Heavy diesel	Mo torcycl e
FC in a hundred kilometers (L/100km)	6.1 0	5 .97	6.96	7.48	9	10	1.7

Equation of calculating each types of vehicle's fuel consumption (g/km) :

$$Cfuel = [cfuel(L/100km) * \rho] / 100 \quad (4)$$

Cfuel: Each types of vehicle's fuel consumption (g/km) ;

cfuel(L/100km): Each types of vehicle's fuel consumption in a hundred kilometers (L/100km) ;

$\rho$ : Fuel density (g/L);

STEP 3: Calculation of CO<sub>2</sub> Emission Factors

Input fuel consumption, CO Emission Factors, THC Emission Factors each types of vehicle's into Equation ① and output CO<sub>2</sub> Emission Factors of each types of vehicle manufactured in Chongqing.

#### 4.2.2 Calculation of CO<sub>2</sub> Emissions of Automotive Operation Process

STEP 1: Product Structure of Chongqing's automotive manufacturing industry in 2005

Data comes from Chinese automotive industry yearbook and Chongqing's governmental report (CAIY, 2006).

STEP 2: Average mileage per year of Chongqing's vehicle in 2005

Data comes from Chongqing Transportation Bureau(Yang, 2009)

STEP 3: Calculation of CO<sub>2</sub> Emissions of Automotive Operation Process

Input CO<sub>2</sub> emission factors, production, average mileage per year into Equation ② and output CO<sub>2</sub> emissions of each types of vehicle manufactured in Chongqing as shown in Table 3.

Table 3 CO<sub>2</sub> Emission of each type of automotives manufactured in Chongqing in 2005

CO <sub>2</sub> Emission (E)	MINI	Saloon	Light gasoline	Light diesel	Medium diesel	Heavy diesel	Motorcycle
CO <sub>2</sub>	67.06	23.73	10.52	47.05	0.10	1.58	34.78

(10,000  
ton)

We can get operation process carbon dioxide emissions of Chongqing's automotive and motorcycle industry of 2005 from totaling the above CO<sub>2</sub> Emission of each type of automotives as 1,848,200 tons.

Table 4 shows the CO<sub>2</sub> Emission per vehicle of each type of automotives manufactured in Chongqing in 2005:

Table 4 CO<sub>2</sub> Emission per vehicle of each type of automotives manufactured in Chongqing in 2005

CO <sub>2</sub> Emission per vehicle (EPV)	MI NI	Sal oon	Light gasoline	Light diesel	Medium diesel	Heavy diesel	Motorcy cle
CO <sub>2</sub> EPV(ton)	1.9 1	1.8 0	1.42	5.09	3.31	9.67	0.08

### 4.3 Results Discussion

The above case showed there are three main emitters during the operation process of automotives manufactured by Chongqing's automotive and motorcycle industry in 2005: Mini cars, motorcycles and saloons which occupied respectively 36.3%, 18.8% and 15.0% of the total emission. While if we look at CO<sub>2</sub> emission per vehicle, we can see that light diesel and heavy diesel vehicles emit much more CO<sub>2</sub> than the other.

According to the national average, material producing process and automotive manufacturing process takes only 10 percent of the CO<sub>2</sub> emission amount during the whole life cycle. Chongqing's automotive and motorcycle industry is advanced compared with other regions in China, the CO<sub>2</sub> emission of the former two processes can be estimated 8 percent. According to the above calculation, the CO<sub>2</sub> emission of operation process is 1,848,200 tons, so that the whole-life cycle CO<sub>2</sub> emission of Chongqing's automotive and motorcycle industry is 1,996,100 tons.

## 5 Summary

There is great significance to make clear of the whole-life cycle CO<sub>2</sub> emission of automotive industry. Starting from the view of manufactures, regional automotive industry whole-life cycle GHGs emissions reflect the present situation of GHGs emissions more correctly, thus measure the contributions the regional automotive manufacturing industry made to reducing GHGs emissions globally. It also benefits the government of making GHGs emissions reducing policies and targets to build environmental friendly society as well as achieve economy growth.



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