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The Establishment of LTO Emission Inventory of Civil Aviation Airports Based on Big Data

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Abstract: An estimation model on LTO emissions of civil aviation airports was developed in this paper, LTO big data was acquired by analysing the internet with Python, while the LTO emissions was dynamically calculated based on daily LTO data, an uncertainty analysis was conducted with Monte Carlo method. Through the model, the emission of LTO in Shuangliu International Airport was calculated , and the characteristics and temporal distribution of LTO in 2015 was analysed. Results indicates that compared with the traditional methods, the model established can calculate the LTO emissions from different types of airplanes more accurately. Based on the hourly LTO information of 302 valid days, it was obtained that the total number of LTO cycles in Chengdu Shuangliu International Airport was 274,645 and the annual amount of emission of SO_2, NO_x, VOCs, CO, PM_{10} and $PM_{2.5}$ was estimated, and the uncertainty of the model was around 7% to 10% varies on pollutants.

1. Introduction

LTO (Landing and Take Off) Cycle defined by International Civil Aviation Organization (ICAO) is the activity data currently widely used in calculation of emission in airports. The statistics in *Official Report of Statistics on Development of Civil Aviation Industry in 2014* [1] issued by Civil Aviation Administration of China showed that by the end of 2014, there were 202 licensed transportation airports in China and the total number of LTO was over 7,933,000 [2]. With the vigorous development of civil aviation industry, the passenger handling capacity of flights increases year by year, more and more attention has been paid to the emission of airplanes. In recent years, a great number of researches on LTO emission have been carried out at home and abroad. In 2008, XIA Qing, et al. established an emission inventory for LTO pollutants in airports of China using emission factors [3]. ZHANG Lijun, et al. established an emission inventory of LTO in Pearl River Delta in 2010[4]. CHEN Lin studied and evaluated the influence of the emission from the air transport industry on environment in 2011 [5]. JERMANTO, et al. also evaluated the LTO emission and the corresponding environmental impacts[6]. In 2013, CAO Huiling, et al. simulated the temporal-spatial concentration distribution of the emissions from civil aviation airports with Gauss diffusion model by Matlab [7]. SONG Lisheng calculated and researched the pollutants discharged by the airplanes of airports in China based on the ICAO airport emission calculation method in 2013 [8]. Sang-Keun Song, et al. conducted a calculation on LTO emission in airports of South Korea [9]. As applications of air quality models increases in China, LTO emission from airports has become a major component of non-road mobile sources. So far, a great number of relevant researches have been conducted at home and abroad [10]. Due to the complexity of flight types, obvious uncertainty exists in traditional methods where the total number of LTO cycles was

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used to estimating the emissions, which was difficult to accurately present the variation of emissions caused by the difference on airplanes types, and most of the current researches focus on NO_x and CO_2 [11] only. Therefore, real-time LTO big data was acquired from the web, based on which an emission model on LTO in airports was developed with Python and R language [12-13] with uncertainty evaluation in this paper.

2. Technologies Adopted

LTO cycles mainly focused on the airplanes activities within the boundary layer, often below 1 Km, including approaching, taxiing, take-off and climbing [14]. The core of establishing an airport LTO dynamic emission inventory model was to acquire the LTO data of different models of airplanes separately in near-realtime and establish an airport LTO emission inventory with the emission-factor approach. When the airport LTO emission model was established based on big data. Python programming language is widely used to acquire big data and R language is currently used in data statistics and analysis extensively. Therefore, Python and R were used in data mining and calculation respectively. The emission-factor approach specified in *Manual on Technique of Preparing Emission Inventory for Non-road Mobile Pollution Sources (Provisional)* [15] ("*manual*" for short hereinafter) was adopted for the emission calculation. The big data on LTO was acquired from the official website of Shuangliu International Airport. Figure 1 shows the overall technological framework.

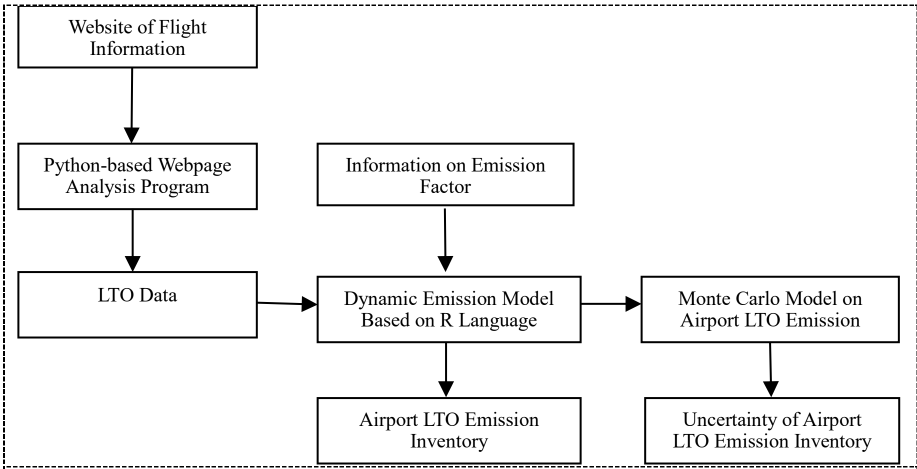

Figure 1. Technologies Adopted

3. Acquisition and Processing of LTO Data

Different airports issue real-time flight information in different ways. In accordance with the degree of complexity, the corresponding data can be directly acquired by viewing network source code， analyzing data transmission mode with browser-based debugging tools, or with packet capture tools. The source code of the webpage of Shuangliu International Airport on issuance of flight information (www.cdairport.com/flight/flightinfo.jsp) includes the method of data requesting in Javascript. The data can be acquired with Python by simulate the POST request, and data required by the calculation of LTO emissions including flight No., information on flight arriving , with leaving and take-off times can be obtained.

Code-sharing flights, which had different flight numbers from different airlines but shared the same airplanes, will cause duplicated count on LTO, so the data need to be separated on the basis of flight numbers with R language, and remove the duplicated airplanes.

4. Airport LTO Emission Model

The dplyr package of R was used in the model to process flight information to acquire the number of hourly LTO cycles of different types of airplanes. With the aforementioned method, the information on arriving at the airport and that on leaving can be acquired separately, thus, each arriving airplanes and the leaving ones was regarded as a half LTO respectively while the sum was regarded as the total LTO that day. The following is the method of estimating the emission of LTO.

$$E_p = 365 \times \sum (LTO_i \times EF_{ip}) \times 10^{-3}$$

In the formula, E_p refers to the annual amount of emission of pollutant p, LTO_i refers to the daily average number of LTO of airplanes i, and EF_{ip} refers to the emission factor of pollutant p emitted from airplanes type i. Therefore, the key to the establishment of dynamic LTO emission model was how to calculate the amount of emission by using the hourly LTO data of each type of airplanes with corresponding emission factors.

The emission factors specified in *Manual* are not classified based on the type of airplanes. Five types of pollutants, i.e. NOx, VOCs, CO, PM_{10} and $PM_{2.5}$ are covered therein. According to the result of research conducted by ZHANG Lijun et al. [4], the emission factor of the domestic airplanes did not vary a lot from that of the overseas ones. And in the work of ZHANG Lijun et al. the emission factors of SO_2, NO_x, VOCs, CO and PM_{10} from 26 types of airplanes currently used for civil aviation were presented without $PM_{2.5}$, in order to establish an emission factor database covering 6 kinds of pollutants in the model including $PM_{2.5}$, the factor of $PM_{2.5}$ was calculated with a ratio of PM_{10} to $PM_{2.5}$ specified in the *Manual* in this study. In addition, the types of airplanes other than the 26 types of airplanes were defined as OTHER, using the emission factors from the *Manual*. The result is shown in Table 1.

Table 1. Emission Factor of Different Types of Airplanes (kg/LTO)

NO.	Model	SO_2	NO_x	VOCs	CO	PM_{10}	$PM_{2.5}$
1	A300	1.63	25.52	1.14	12.21	0.15	0.15
2	A310	1.51	22.15	1.11	11.1	0.09	0.09
3	A319	0.69	8.42	1.69	7.76	0.03	0.03
4	A320	0.8	10.95	0.7	5.96	0.08	0.08
5	A321	0.97	17.02	0.07	3.96	0.12	0.12
6	A330	2.08	34.71	1.19	13.63	0.03	0.03
7	A340	2.14	40.04	2.99	20.02	0.13	0.13
8	B707	1.75	10.81	90.85	79.69	5.6	5.50
9	B727	1.36	12.3	1.24	7.71	0.46	0.45
10	B737	0.87	12.83	1.01	8.6	0.13	0.13
11	B747	3.21	49.85	4.81	29.74	0.24	0.24
12	B757	1.29	23.63	0.21	6.94	0.01	0.01
13	B767	1.64	25.09	1.1	11.05	0.11	0.11
14	B777	2.3	47.26	1.11	13.72	0.12	0.12
15	CL60	0.16	2.3	0.93	6.01	0.03	0.03
16	DC10	2.48	37.01	10.44	43.58	0.25	0.25
17	DC8	1.82	11.56	92.22	102.45	2.3	2.26
18	DC9	0.81	6.91	1.35	5.59	0.12	0.12
19	DF3	0.14	2.5	1.11	5.87		
20	F100	0.7	5.12	0.5	7.44	0.1	0.10
21	GRJ	0.64	5.59	1.3	7.61	0.38	0.37
22	L1011	2.41	40.4	65.93	95.1	0.88	0.86
23	LRJ	0.18	0.64	3.35	34.62		

NO.	Model	SO_2	NO_x	VOCs	CO	PM_{10}	$PM_{2.5}$
24	MD11	2.52	39.46	1.43	16.4	0.2	0.20
25	MD80	0.95	11.93	1.81	5.66	0.24	0.24
26	MD90	0.82	10.64	0.06	4.77	0.1	0.10
27	OTHER	1.38	16.29	2.68	9.14	0.54	0.53

In the process of developing the model, different modules were written to realize different functions. Firstly, LTO data were read and sorted out, flight information was extracted and the number of hourly LTO cycles was integrated by type. Then, the hourly LTO data were analyzed and matched with the emission factors separately. At last, the amount of emission of different types of airplanes per day was calculated with the emission factor method, and the annual amount of emission was acquired, accordingly. Besides, in the model, the statistical diagram needed to be drawn and uncertainty needed to be calculated with corresponding codes. Parallel computing was realized with doParallel package to speed up the model [16]. Codes of the emission model established in this study can be acquired from the website after publish (github.com/airmonster/DynaLTO).

5. Analysis on LTO of Shuangliu International Airport

In 2014, the number of LTO cycles in Chengdu Shuangliu International Airport was over 270000. The LTO data from April 2015 to April 2016 was used in this study. The data of only 302 days were valid due to network failure. Figure 2 shows the temporal distribution of LTO in Shuangliu International Airport.

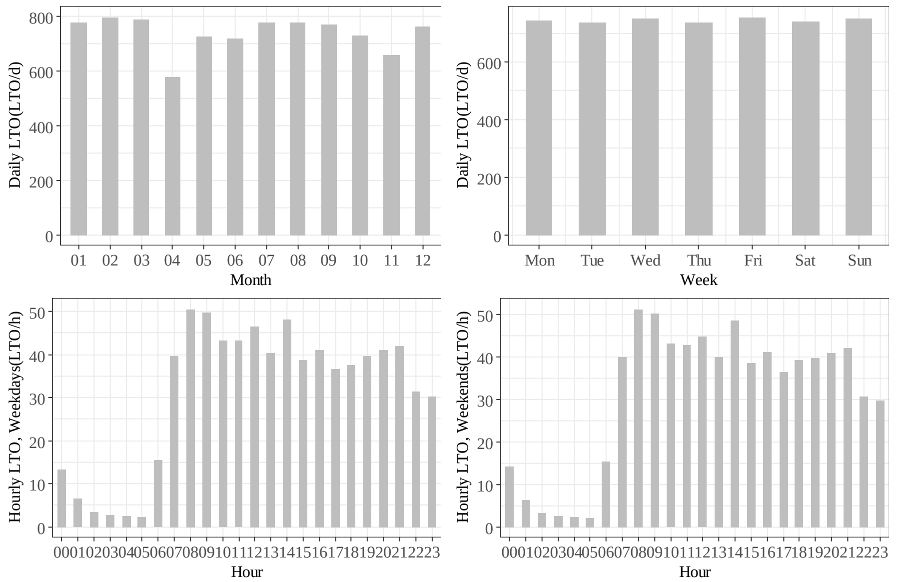

Figure 2. Temporal Distribution of LTO

LTO cycles in Shuangliu International Airport had obvious characteristics of hourly distribution. From 1:00 to 5:00, the proportion of hourly distribution of LTO was less than 1%. LTO started to increase at 7:00, reached the maximum value of the day at 8:00 and then declined, with another peak at 12:00 and 14:00 respectively. At 23:00, LTO started to decrease. Hourly distribution on weekdays did not vary much from weekends. The weekly variation of LTO was relatively consistent.

By types, A320, A321 and A319 were the major types of airplanes in Shuangliu International Airport. The number of LTO cycles of the three types accounted for 65.73% of the total. The proportion of LTO cycles of A330, B737 and OTHER was 11.28%, 16.98% and 6.00% respectively. OTHER were mainly from Boeing Company, which accounted for 57.35% including B772 (12.74%), B77W (9.79%), B752 (7.48%) and B788 (5.65%). 11.77% of the types of airplanes was from Airbus, such as A380 (2.79%) and A388 (3.08%), etc. And the information on types of airplanes of nearly 7% of flights was not provided. The total number of LTO cycles of other types of airplanes accounted for a small part so the corresponding emission factors were not furtherly collected in this study. Table 2 shows the annual number of times of LTO of each type of airplanes.

Table 2. Proportion of LTO in Shuangliu International Airport

Model	A319	A320	A321	A330	B737	OTHER
LTO	48271.25	75786.17	56474.63	30993.37	46629.36	16490.09
Proportion	17.58%	27.59%	20.56%	11.28%	16.98%	6.00%

6. Comparison on Model Results

The emission was calculated with the method herein and with the emission factors specified in *Manual* separately, as shown in Table 3.

Table 3. Comparison on Results

Description	Annual LTO	SO_2	NO_x	VOCs	CO	PM_{10}	$PM_{2.5}$
This study	274644.86	276.50	4140.16	266.75	2024.08	30.18	29.63
Factors from manual	274644.86	379.01	4473.96	736.05	2510.25	148.31	145.56

The LTO covering 94% types of airplanes were acquired in this study, therefore, obvious differences existed between the result from the model herein and that calculated based on the *Manual*, especially on VOCs, PM_{10} and $PM_{2.5}$. In general, the result of the model herein was lower than the *Manual* ones.

7. Uncertainty Analysis

The activity data, daily LTO, were acquired from the official website of Shuangliu International Airport, with relatively high accuracy. Therefore, when calculation was conducted on annual LTO emission, uncertainty mainly came from the variation in the number of daily LTO cycles of different airplane types. The LTO distribution of A320 and A321 is shown in Figure 3, as an example.

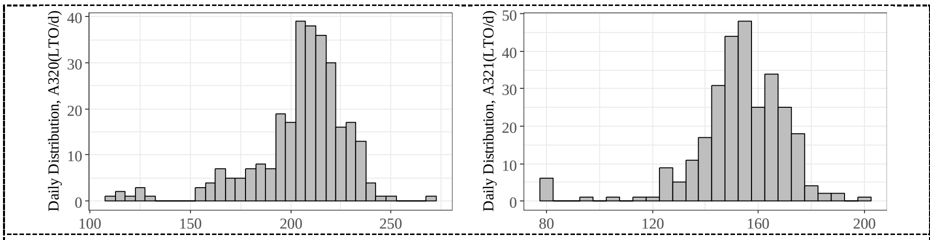

Figure 3. Histogram on Daily Average LTO of Types of Airplanes

It was presumed that in a year, the number of times of LTO of each type of airplanes should have been in conformity with Gaussian distribution every day, Gaussian distributed random numbers were generated based on the average value and standard deviation of LTO of different airplane types, and a Monte Carlo simulation was carried out for one million times[17], the annual amount of emission of Shuangliu International Airport was calculated and the uncertainty was represented using relative standard deviation [18]. The result was shown in Table 4.

Table 4. Uncertainty of Method

	SO_2	NO_x	VOCs	CO	PM_{10}	$PM_{2.5}$
Simulation Results	276.49	4139.58	266.78	2024.3	30.19	29.62
Uncertainty	7.35%	7.55%	8.72%	7.28%	10.56%	10.59%

The uncertainty of PM_{10} and $PM_{2.5}$ was relatively high, around 10%, while that of VOCs was around 9%, other pollutants was around 7%. In addition, in this study, the emission factors were not selected by the type of airplane engines but acquired from the existing researches based on the airplane type, which should be improved. At the same time, the emission factors were mainly based on the ICAO emission factors from tests under the lab conditions, with 7%, 30%, 85% or 100% of power output, which were not exactly the same as those in real situations, ignoring the actual load of flights and the meteorological characteristics for example, which may enlarge the uncertainty.

8. Conclusions

The flight information could be acquired steadily and reliably with the method adopted herein. Through model calculation, it was obtained that the number of times of LTO cycles in Chengdu Shuangliu International Airport in 2015 was 274645 and the annual amount of emission of SO_2, NOx, VOCs, CO, PM_{10} and $PM_{2.5}$ was 276.50t, 4140.16t, 266.75t, 2024.08t, 30.18t and 29.63t respectively. The result of Monte Carlo simulation shows that the uncertainty of SO_2, NOx and CO resulting from that of LTO was around 7%, and VOCs about 9%, while the uncertainty of PM_{10} and $PM_{2.5}$ was around 10%. It was difficult to carry out quantitative analysis on the uncertainty arising from other elements. In this model, data acquisition and analytical calculation were divided into two parts and conducted separately, which could be applied in different kinds of environment and regions.

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