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Calibration of the Number of Registered Vehicles for Estimating Regional Vehicle Emissions

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Abstract: This study reviewed the method of replacing the number of registered vehicles with the number of trips to more realistically calculate vehicle emissions. Using the Korea Transport Data Base (KTDB) in replacing the number of registered vehicles with number of trips by specific vehicle type in the metropolitan area, the results by region showed that Seoul had the widest rate of error and that, among vehicles, trucks had the widest rate of error. Also, the absolute value of deviation of registered vehicles and trips influenced by the calculation of the quantity of vehicle emissions showed that out of the metropolitan regional government all trucks showed the widest deviation. The results of calculating the quantity of vehicle emissions showed an average of 9% difference between the emissions based on the number of registered vehicles and the emissions based on trips.

Keywords: Diesel Vehicle, Vehicle Emission, Registered Vehicle, Trips, KTDB

1. INTRODUCTION

The quantity of total air pollution emissions by the 2011 standards stood at 3,543,852 tons and out of this the quantity of vehicle emissions stood at 877,514 tons (24.8%), the largest out of all sources of emissions. This was especially true for CO, and NO_X which made up 64.5% and 31.0%, respectively (National Institute Environmental Research, 2014), of the quantity of emissions, emphasizing on the importance of managing vehicle emissions for improving air quality. In case of metropolitan areas, since 2015 the 2nd comprehensive plans to improve air quality in metropolitan areas have been underway, and as for the management plans for vehicle emissions, there would be an increased supply of eco-friendly cars and an elevated management of vehicle emissions. Likewise, in order to boost effectiveness for the management of vehicle emissions by the regional government, it is necessary to accurately calculate the quantity of emissions prior to and after the implementation of the management plan.

The quantity of vehicle emissions is generally calculated by the number of registered vehicles (National Institute Environmental Research, 2013). But, while this method of calculating the total quantity of emissions in the country is not exactly exaggerated, it is determined to have its limits when it comes to a detailed calculation of the quantity of emissions by specific regions. Meaning, in order to calculate the detailed emissions of a specific area by registered vehicles one has to consider the number of registered vehicles in the target region, the other regions they would cross over into and vehicles coming into that area, and this leads to the necessity of the concept of the trips rather than the number of registered vehicles. In particular, in case of trucks that tend to have a high proportion of NO_X emissions, there is a low concordance between the location of vehicle registration and locations of travel leading to the possibility of the quantity of emissions being overrepresented or underrepresented (The Korea Transport Institute, 2011).

This study seeks to review plans to replace the number of registered vehicles with trips to more realistically calculate the quantity of vehicle emissions by the regional government. National transport survey results were used for this study, and the results of calculating the quantity of emissions based on registered vehicles was compared with the results of calculating the quantity of emissions based on trips to review the feasibility of application of trips using the data for calculating the vehicle emissions by the regional government.

This study selected metropolitan areas with their numerous registered vehicles and trips throughout Korea as target regions to review the plan for calculating the quantity of vehicle emissions. Target vehicles for calculating the quantity of emissions included diesel vehicles that are 10 years old or older and are not participating in the exhaust gas reduction scheme, and air pollutants were limited to PM_{10} and NO_X which are usually released from diesel vehicles.

2. LITERATURE REVIEW

The calculation of the quantity of vehicle emissions was done according to the methods presented in the IPCC (Intergovernmental Panel on Climate Change), and followed the method displayed in the 2006 IPCC guidelines for calculating the quantity of vehicle emissions presenting Tier 1 based on the fuel consumption rate, Tier 2 based on the fuel consumption by vehicle type, and Tier 3 based on vehicle kilometer travelled (VKT). The National Institute Environmental Research (2013) shows the method of calculating the national quantity of total air pollution emissions in Korea, and the quantity of vehicle emissions was calculated using the total VKT and emissions coefficient taking into consideration the number of registered vehicles by vehicle type.

However, in various studies, Tier 3 is appropriate when calculating the quantity of vehicle emissions by regional government, and to emphasize the necessity of collecting data to apply this method (Kim et al. 2010; Yu ea al. 2011; Kim et al. 2011; Kim et al. 2012; Lee et al, 2012). Also, ongoing research is being conducted to improve on Tier 3 to more accurately calculate the quantity of vehicle emissions (Choi et al. 2009; Lee et al. 2012; Gwon, 2014), and the greenhouse gas emissions output model which used the Korea Transport Data Base (KTDB) has also been reviewed (Park et al. 2013).

The development of tools that can analyze the quantity of vehicle emissions is also being conducted at a brisk pace in Korea and overseas. The TREMOVE, which has been developed at the Catholic University of Leuven and Transport & Mobility Leuven can calculate the quantity of greenhouse gas emissions emitted not only from passenger transport, but from freight transport as well, and it is possible to analyze the various policy scenario effects in the transport category by combining the traffic demand model and a model to calculate the quantity of greenhouse gas emissions into one.

The results of a comparison with a previous study show that in case of Korea, tool development for the analysis of the quantity of vehicle emissions is lacking, and it is also not easy to collect the data to apply the Tier 3 resulting in various limitations to varying the analysis of the air management policy effects. Accordingly, for the long term, plans should be reviewed in which the various tool development and related data can be secured for methods of calculating the quantity of vehicle emissions as seen in the foreign and domestic cases, and for the short term, it is determined that the plan should be reviewed to improve the existing methods of calculating the quantity of vehicle emissions. From the short term perspective, this study reviewed the method of replacing the basic variable, the number of registered vehicles, when calculating the quantity of emissions, with the trips instead to more realistically calculate the quantity of vehicle emissions by regional government.

Model	Geographic Level of Analysis				Type of Analysis			Transportation Mode						
	State	Region	Local	Project	Inventory Develop-ment	Projections	Strategy Analysis	Light-duty Vehicles	Heavy-duty Trucks	Buses	Rail	Maritime	Aviation	Other Non-road
MOBILE6	■	■	■	■	■	■	■	■	■	■	-	-	-	-
NONROAD	■	■	■	-	■	■	■	-	■ off-road only	-	-	■ non-freight	-	■
NMIM	■	■	■	-	■	■	■	■	■	■	-	-	-	■
SIT	■	-	-	-	■	-	-	■	■	■	■	■	■	■
SIPT	■	-	-	-	-	■	-	■	■	■	■	■	■	■
CLIP	-	-	■	-	■	-	■	■	■	■	-	■ non-freight	-	■
MOVES	■	■	■	■	■	■	■	■	■	■	2007 release	2007 release	2007 release	2007 release
COMMUTER	□	■	■	■	-	-	■ TDM projects	■	-	-	-	-	-	-
IDAS	□	■	■	■	-	■	■ ITS projects	■	■	■	■	-	-	-
NEMS	□	-	-	-	-	■	■	■	■	■	■	■	■	■
VISION	□	-	-	-	-	■	■	■	■	-	-	-	-	-
WEPS	□	-	-	-	■	■	■	■	■	■	■	■	■	■
SAGE	□	-	-	■	■	■	■	■	■	■	-	-	-	-
GREET	■	■	■	■	■	■	■	■	-	-	-	-	-	-
LEM	□	-	-	-	■	■	■	■	■	■	■	■	-	■ pipelines
EMFAC	■	■	■	■	■	■	■	■	■	■	-	-	-	-
NYSDOT	■	■	■	■	-	■	■	■	■	■	■ non-freight	-	-	■

Key
■ Designed for this type of analysis
□ Not designed for this type of analysis but could potentially be applied
- Not applicable

Figure 1. Applicability of tools for transportation GHG analysis

3. METHODOLOGY

3.1 Data

3.1.1 The number of registered vehicle by region

An exhaust gas reduction scheme has been implemented since 2005 in the metropolitan area targeting diesel vehicles in operation. The exhaust gas reduction scheme is a project that attracts measures for low emissions or early demolition of the vehicle in order for vehicles that have passed their exhaust gas warranty period to maintain the emissions quality standards. This study, due to the limits in data collection, was conducted targeting vehicles with a total weight of more than 2.5 tons, and old diesel vehicles that are 10 years old or older and are not participating in the exhaust gas reduction scheme, and the results have been organized by city and province as see in Table 1. There are 429,537 vehicles registered in the metropolitan area making up 28% of the total number of registered vehicles in the country, and when examining the data by city and province, Gyeonggi Province had the largest number of registered vehicles overall.

Also, the results of reviewing the target vehicles by vehicle production from 1995 to 2005 as in Figure 2 show that the distribution of vehicles registered in the metropolitan area and non-metropolitan area was generally the same. But, the metropolitan area had many more registered trucks that were 1995 models or older compared to the non-metropolitan area resulting in the view that the metropolitan area has a greater concordance of trips that are 20 years or older when compared to non-metropolitan areas.

Table 1. The number of registered vehicles that are not participating in the exhaust gas reduction scheme

Region	RV	Van	Truck	Sum
Seoul	49,018	13,731	52,569	115,318
Busan	16,862	10,867	59,179	86,908
Daegu	14,806	7,429	57,814	80,049
Incheon	21,543	6,326	27,868	55,737
Gwangju	10,049	4,079	32,299	46,427
Daejeon	10,965	4,806	28,222	43,993
Ulsan	9,207	3,225	22,366	34,798
Sejong	1,155	541	4,414	6,110
Gyeonggi	94,328	27,958	136,196	258,482
Kangwon	13,531	6,407	57,615	77,553
Chungbuk	13,251	6,375	59,014	78,640
Chungnam	18,046	8,457	82,478	108,981
Chonbug	13,948	7,318	78,667	99,933
Chonnam	14,592	8,348	95,862	118,802
Gyeongbuk	21,071	12,473	133,142	166,686
Gyeongnam	21,958	13,229	114,002	149,189
Sum	344,330	141,569	1,041,707	1,527,606

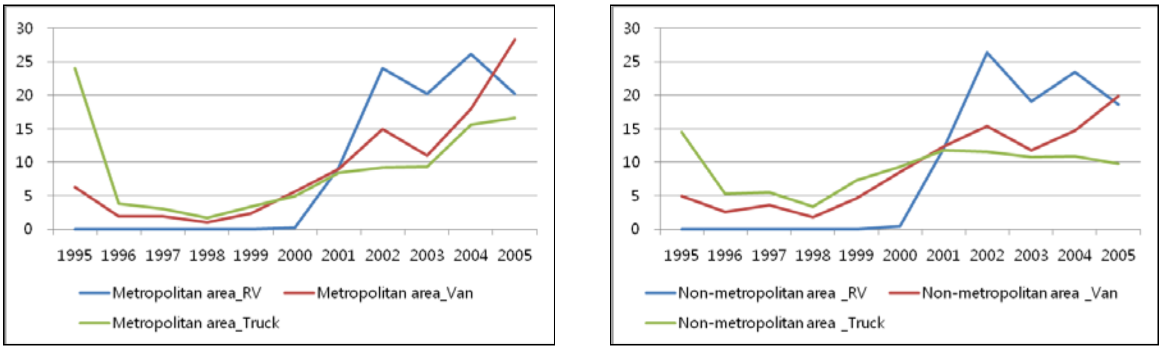


Figure 2. The distribution of production from 1995 to 2005 by region

3.1.2 National transport survey

The national transport survey conducted every 5 years is broadly classified into passenger and freight. Passenger survey was last conducted in 2010 and a freight survey in 2011. This study used passenger and freight origin-destination trip matrix (O/D) data from the national survey results, and the surveys related with the O/D data are household travel survey and truck traffic survey. The household travel survey was conducted to determine the attributes of the target household and the household members’ daily weekday travel, and the truck traffic survey was conducted to gage the daily travel log of trucks to analyze the status of freight movement throughout the country.

3.1.3 Emission coefficient

The Ministry of Environment provides an emissions coefficient to calculate the quantity of emissions of vehicles operated in the metropolitan area. This study used this coefficient to calculate the quantity of emissions, and the emissions coefficient features by air pollutant for each vehicle type in this study is shown under Figure 3 and Figure 4. The emissions coefficient of PM_{10} and NO_X showed that all old mid-sized and large vehicles (van, truck) had high levels, and in particular the emissions coefficient of NO_X showed an approximately 10 times higher emissions coefficient of PM_{10}.

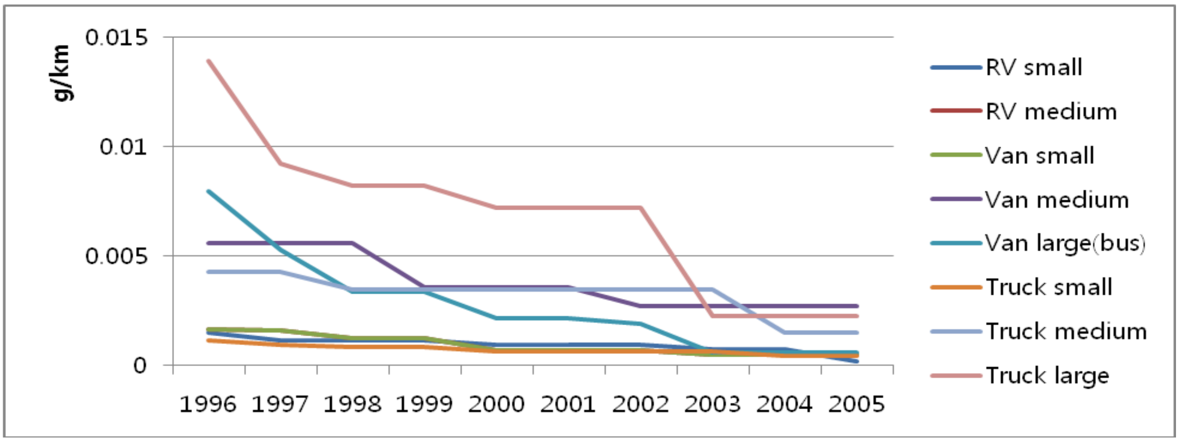


Figure 3. The characteristic of emission coefficient (PM_{10})

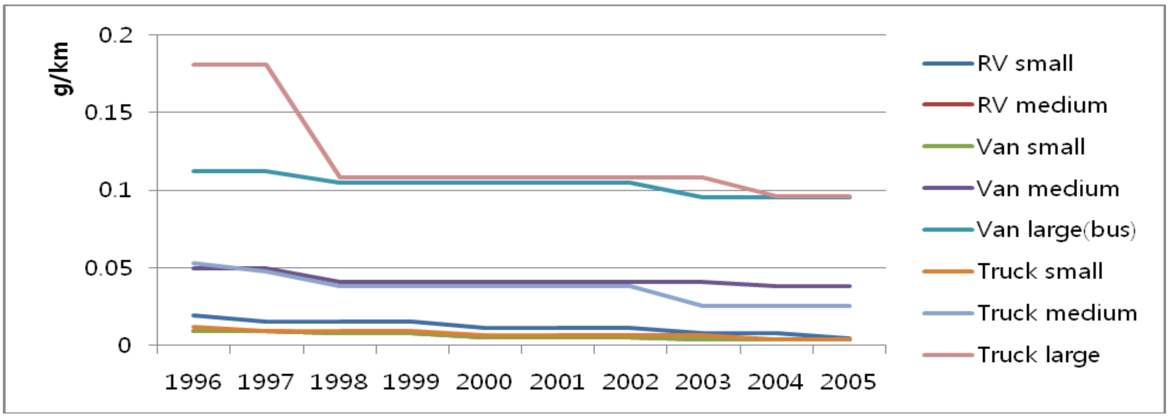


Figure 4. The characteristic of emission coefficient (NO_X)

3.2 Calibration of the Number of Registered Vehicles

As stated above, this study reviewed the method of replacing the number of registered vehicles with the trips to more realistically calculate the quantity of vehicle emissions by regional government using the O/D data. The O/D data provided by the KTDB is in matrix form as shown in Figure 6, and through the relevant data one can obtain information about the amount of trip generation (O_i), the amount of trip attraction (D_j), interregional trips (T_{ij}), and intra-regional trips by region (T'_{ij}). It is possible to classify interregional passenger O/D matrix by travel mode (auto, bus) and interregional freight O/D matrix by truck tonnage (small, medium, large) making it possible to have a rough matching by data on vehicle type of existing registered vehicles data.

OD	Z1	Z2	Z3	O
Z1	T11	T12	T13	O1
Z2	T21	T22	T23	O2
Z3	T31	T32	T33	O3
D	D1	D2	D3	TT

Z_i : Region(traffic zone)

O_i : Trip generation by zone(trip/day)

D_j : Trip attraction by zone(trip/day)

T_{ij} : Interregional trips($i \neq j$)(trip/day)

T'_{ij} : Intra-regional trips by region($i = j$) (trip/day)

TT : Total trips (trip/day)

$i, j = 1,2,3$

Figure 5. Interregional O/D data matrix

On the other hand, in case of 3 regions as in Figure 5, the following way will be used to replace the number of registered vehicles with trips in region Z_i

$$A_i' = A_i - \{A_i \times ((T_{ij} + T_{ik}) / O_i)\} + \{A_j \times T_{ji} / O_j + A_k \times T_{ki} / O_k\} \quad (1)$$

where,

A_i' : Trips of region Z_i

A_i : The registered vehicles of region Z_i, and

$i,\ j,\ k = 1,\ 2,\ 3 (i \neq j \neq k)$.

Fundamentally, the number of registered vehicles in region Z_i was not consistent with the trips in region Z_i. This is because vehicles registered in region Z_i not only operate outside of region Z_i, and vehicles registered outside the region can also pass through region Z_i. In line with this, this study considered the number of registered vehicles in region Z_i and the number of registered vehicles traveling from region Z_i into other regions ($A_i \times ((T_{ij} + T_{ik}) / O_i)$) and considered the number of registered vehicles entering region Z_i from other regions ($A_j \times T_{ji} / O_j + A_k \times T_{ki} / O_k$) for reviewing a method to estimate the trips (A_i') of region Z_i.

4. ANALYSIS

4.1 Estimation of the Number of Travel Vehicles

Eq. (1) was used in calculating the quantity of vehicle emissions and the result of replacing the number of registered vehicles in the metropolitan area with the trips are as follows. Table 2 shows the results of an estimation using O/D data for the number of vehicles registered to the metropolitan area crossing into other regions and the number of vehicles registered to other areas entering the metropolitan area. Also, the result of Table 3 is estimated using the result of Table 2, and is a comparison of the results of replacing the number of registered vehicles with the trips and existing registered vehicles of the metropolitan area.

Table 2. The number of registered vehicles of metropolitan area

Type		Metropolitan area→Other regions			Other regions→Metropolitan area		
		Seoul	Incheon	Gyeonggi	Seoul	Incheon	Gyeonggi
RV	Small	787	308	1,166	992	304	918
	Medium	9,504	3,979	14,519	12,437	3,752	11,356
Bus	intra	121	41	526	121	41	526
	intercity	21	7	93	105	16	39
	chartered	40	19	138	201	40	101
	express	17	5	31	36	6	23
	other	22	6	75	102	20	50
Van	Small	2,589	1,154	4,002	3,552	1,045	3,307
	Medium	68	29	143	135	36	110
	Large	47	10	37	33	12	50
Truck	Small	7,805	5,479	23,907	17,497	6,255	19,217
	Medium	3,908	1,735	8,051	3,828	1,970	9,222
	Large	1,546	1,404	6,200	1,860	1,894	7,264
Sum		26,475	14,176	58,888	40,899	15,391	52,183

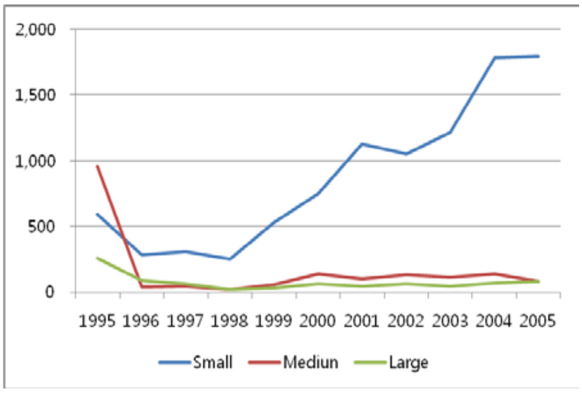
Table 3. Comparison of the trips and the number of registered vehicles of metropolitan area

Type		Trips			Registered vehicles			Error rate(%)		
		S	I	G	S	I	G	S	I	G
R	Small	3,954	1,543	6,764	3,750	1,547	7,012	5.45	-0.26	-3.54
	Medium	48,201	19,769	84,153	45,268	19,996	87,316	6.48	-1.13	-3.62
B	intra	121	41	526	121	41	526	0.00	0.00	0.00
	Intercity	238	62	578	155	53	632	53.82	17.25	-8.57
	chartered	452	170	899	291	149	935	55.31	14.15	-3.88
	express	142	42	202	122	41	210	16.14	2.06	-3.74
	other	244	58	483	165	44	508	47.91	32.37	-4.93
V	Small	13,293	5,691	23,373	12,329	5,800	24,068	7.82	-1.88	-2.89
	Medium	390	154	825	323	147	858	20.67	4.74	-3.83
	Large	211	53	234	225	51	221	-6.40	4.13	5.96
T	Small	52,349	23,950	104,773	42,658	23,174	109,462	22.72	3.35	-4.28
	Medium	7,021	3,238	19,001	7,101	3,003	17,830	-1.13	7.83	6.57
	Large	3,124	2,182	9,968	2,810	1,691	8,904	11.17	29.01	11.95
Sum		129,739	56,953	251,778	115,318	55,737	258,482	12.51	2.18	-2.59

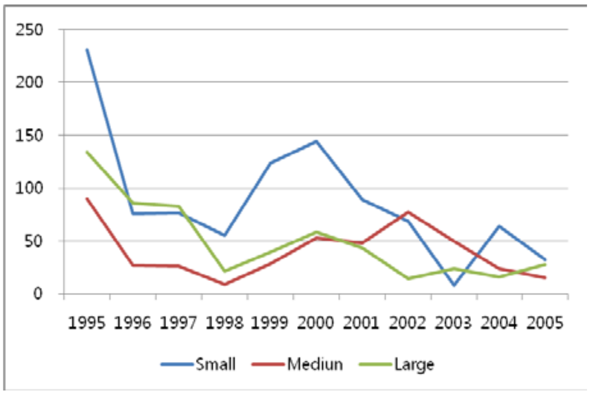
S: Seoul; I: Incheon; G: Gyeonggi; R: RV; B: Bus; V: Van; T: Truck.

The results of comparing registered vehicles in the metropolitan area with trips by specific car types (RV, van, bus, truck) showed that by region, Seoul showed the widest rate of error of 12.51%. In Seoul the widest rate of error was shown in charter buses and in Incheon and Gyeonggi, other buses and large trucks showed the widest rate of error, respectively. Meanwhile, compared with other vehicle types, all trucks in the Seoul, Incheon and Gyeonggi region showed the greatest difference for the absolute value of deviation for registered vehicles and trips that could affect the quantity of emissions calculation. This leads to the view that a method to replace the number of registered vehicles for trucks is of utmost importance.

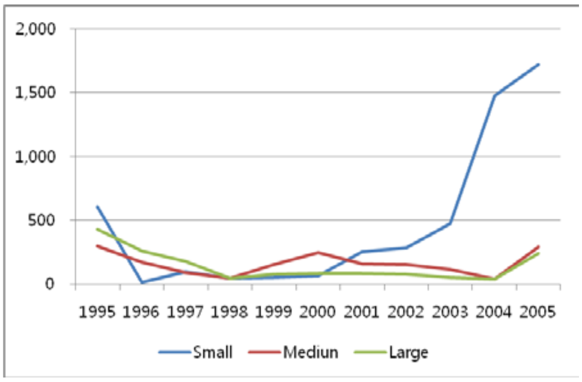
However, the result of comparing the absolute value deviation of trucks in the metropolitan area by tonnage and model year for the number of registered vehicles and the trips are as follows. In Seoul and Gyeonggi, the later the model the greater the absolute value deviation for small trucks, but mid-sized and large trucks showed the characteristics of a lesser absolute value deviation. Generally, the later the model, the greater the emissions coefficient; so it was determined that the basic result of calculating emissions by the number of registered vehicles and the result of calculating emissions by the trips was a standout difference in case of Seoul and Gyeonggi for mid-sized and large trucks, and in case of Incheon for all truck tonnage.



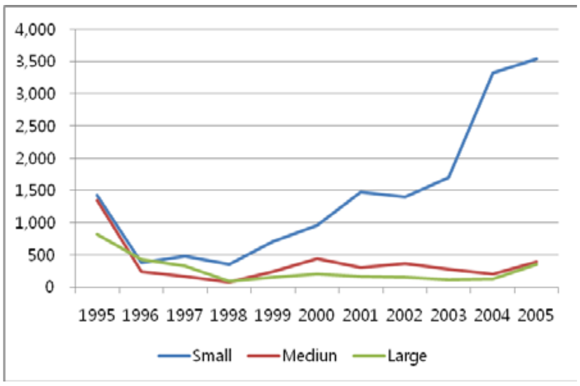
Seoul



Incheon



Gyeonggi



Metropolitan area

Figure 6. The result of comparing the absolute value deviation of trucks by regions

4.2 Estimation of Vehicle Emissions

Emissions were calculated by specific vehicle type (RV, van, bus, truck) in the metropolitan area to compare the results of calculating emissions by registered vehicles with the results of calculating basic emissions by trips as presented in this study. For convenience sake, in this study, the calculation for vehicle emissions was performed with the concept of total amount, and the method of calculation was performed as follows. The emissions coefficient and thermal coefficient used data provided by the Ministry of Environment (2014) and the National Institute of Environmental Research (2013), respectively, and the value in Korea Transportation Safety Authority (2013) was used for the daily average VKT.

$$\begin{aligned}\text{Emissions} = &\text{ Emission coefficient} \times \text{Thermal coefficient} \\ &\times \text{the number of registered vehicles(trips)} \\ &\times \text{daily average VKT} \times 365\end{aligned} \tag{2}$$

The results of calculating emissions by air pollutant are shown in Table 4. The results of calculating emissions by the number of registered vehicles with the metropolitan area as the criteria and the results of calculating emissions by the trips showed an error of 9%, with the rate of error of the metropolitan regional governments being the greatest in Incheon. Further, the outcome of comparing the results of calculating the emissions by air pollutant for Incheon with the results by vehicle model is as shown in Figure 7, with vans, RV, buses and trucks, in that order, showing the widest rate of error for PM_{10} and NO_X.

Table 4. The result of vehicle emissions by air pollutant and by regions

Region	PM_{10}			NO_X		
	Registered vehicles(ton)	Passing vehicles(ton)	Error rate(%)	Registered vehicles(ton)	Passing vehicles(ton)	Error rate(%)
M	1,616	1,749	8.22	22,555	24,587	9.01
S	496	533	7.30	6,433	7,213	12.12
I	217	258	18.95	2,816	3,375	19.83
G	903	958	6.15	13,306	13,999	5.21

M: Metropolitan area; S: Seoul; I: Incheon; G: Gyeonggi.

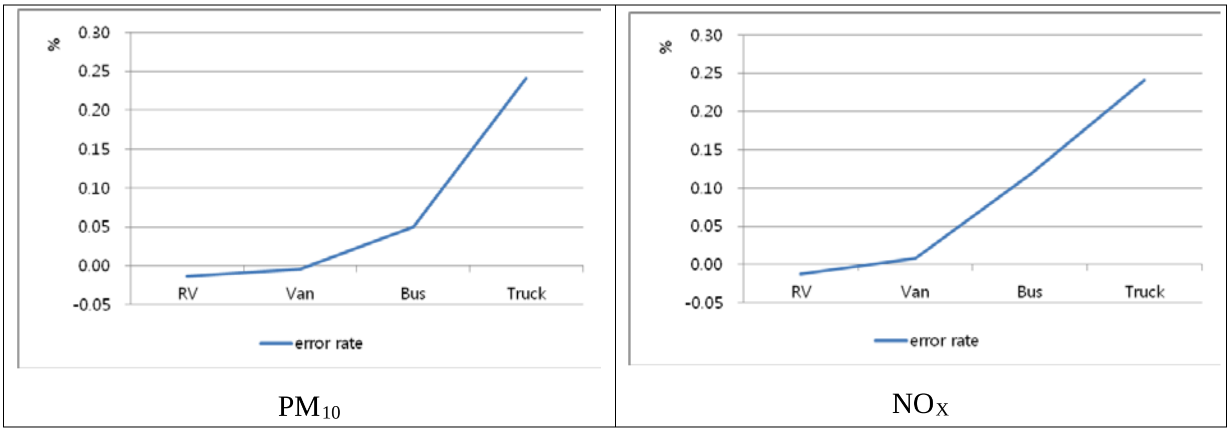


Figure 7. The comparison of vehicle emissions error rate by vehicle type (Incheon)

So, the biggest reason for the rate of error in Incheon, as reviewed in Figure 7, was that differing from Seoul and Gyeonggi, it was shown that Incheon had a wide absolute value deviation for older models in the number of trucks registered by tonnage and the truck trips. Meaning, the trucks were the type of vehicle that most greatly affected all results when calculating emissions in metropolitan regional government, and in the case of Incheon compared with Seoul and Gyeonggi, the absolute value deviation of the number of registered old trucks with trips was seen as relatively wide. Thus, there was a wide rate of error in the results of calculating the quantity of vehicle emissions.

The results of calculating emissions by air pollutant and by vehicle type are shown in Table 5, and the rate of error for PM_{10} and NO_X in all buses and trucks are all relatively wide based on the criteria for metropolitan areas. However, the result of reviewing trucks by tonnage and model year for the number of registered vehicles and the trips are shown in

Figure 8, and the greater the tonnage of the truck the wider the rate of error, especially for trucks manufactured between 1996 and 2000 showing the widest rate of error. Based on such results it was determined that a priority should be placed on the maintenance of large trucks with an early production date in order to boost the effectiveness of improving air quality.

Table 5. The result of vehicle emissions by vehicle types

Type	PM_{10}			NO_X		
	Registered vehicles(ton)	Passing vehicles(ton)	Error rate(%)	Registered vehicles(ton)	Passing vehicles(ton)	Error rate(%)
RV	156	156	-0.02	1,358	1,361	0.24
Bus	243	256	5.45	5,206	5,583	7.24
Van	41	42	0.96	413	418	1.11
Truck	1,176	1,295	10.15	15,579	17,225	10.57

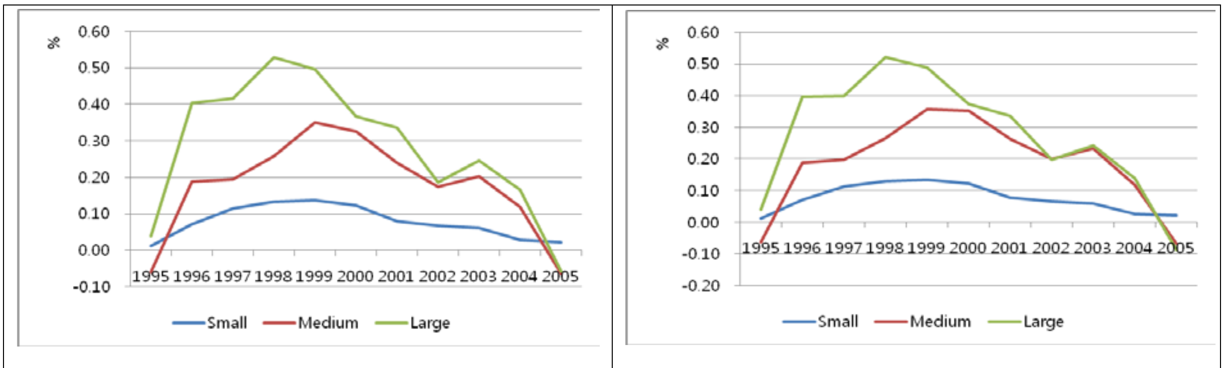


Figure 8. The comparison of emissions error rate by truck types and production year

The results of comparing the calculation of the quantity of emissions for air pollutant by production year are shown in Table 6, and Table 7 and the rate of error for PM_{10} and NO_X for production years between 1996 and 2000 were relatively wide. Also, the result of comparing the rate of error by production year is shown in Figure 9. The rate of error for PM_{10} and NO_X for Incheon for production years prior to 2000, and the rate of error for Seoul for production years prior to 2000 were the widest. As mentioned above, the older and larger the vehicle is, the larger the emissions coefficient, and in case of Incheon the number of vehicles that are registered as mid-sized and large trucks with old production years and the absolute value deviation of the trips was relatively greater when compared to Seoul and Gyeonggi.

Table 6. The comparison of emissions by production year (PM_{10})

Type	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Sum
R	827	127	68	18	35	52	78	128	77	94	111	1,61 6
P	839	164	89	24	46	67	90	139	82	98	111	1,74 9
E	1.4	29.1	29.9	30.4	31.0	27.4	15.3	8.9	7.7	4.8	-0.4	8.2

R: Registered vehicle(ton); P: Passing vehicle(ton), E: Error rate(%)

Table 7. The comparison of emissions by production year (NO_X)

Type	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Sum
R	104	16	11	3	5	8	10	16	11	17	25	226
P	106	20	15	3	6	10	12	18	13	19	25	246
E	1.3	28.6	30.9	28.9	30.3	27.9	18.7	12.4	12.1	9.0	-0.4	9.0

R: Registered vehicle(100ton); P: Passing vehicle(100ton), E: Error rate(%)

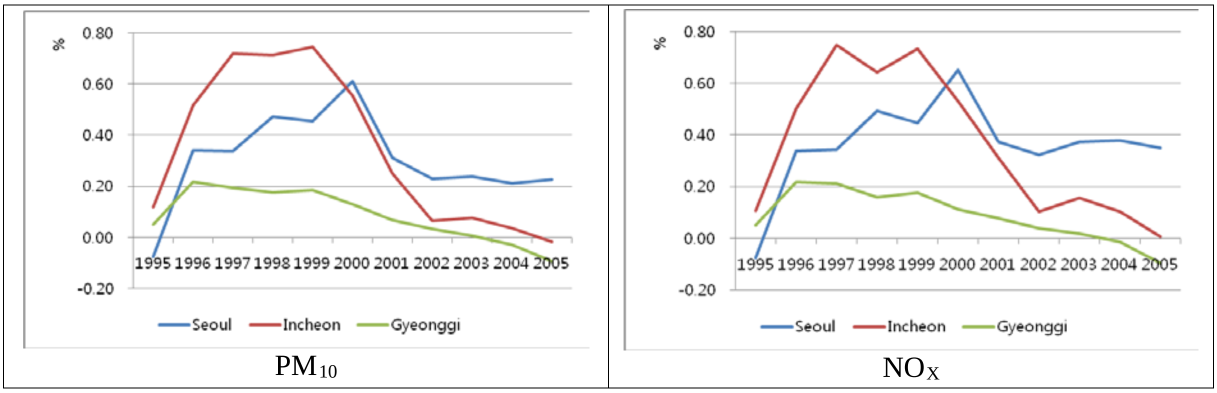


Figure 9. The comparison of emissions error rate by regions and by production year

5. CONCLUSIONS

This study sought to find a way to replace the number of registered vehicles with trips to more realistically calculate the quantity of vehicle emissions by regional government. The results of replacing the number of registered vehicles with trips of specific vehicle types (RV, van, bus, truck) in the metropolitan area using the interregional passenger and freight O/D data showed that the rate of error for buses and trucks was wide. Also, the absolute value of deviation of the number of registered vehicles and the trips that influenced the calculation of the quantity of emissions placed all trucks as the greatest, and such results suggest that when calculating the vehicle emissions based on the number of registered vehicles it is necessary to review this from diverse viewpoints.

The results of reviewing the absolute value of deviation by tonnage and production year for the number of registered vehicles and the trips targeting trucks in the metropolitan area like Seoul and Gyeonggi show that the later the production year the greater the absolute value deviation, but for mid-sized and full-sized trucks the absolute value deviation grew smaller. On the other hand, regardless of tonnage, trucks in Incheon featured smaller absolute value deviation the later the model year. Generally, when one considers that older mid-sized and large vehicles have a larger emissions coefficient, then in the results of calculating the quantity of emissions based on the number of registered vehicles and calculating the quantity of emissions based on the trips in case of Seoul and Gyeonggi the mid-sized and large trucks are estimated to standout, but for Incheon it would be all tonnage of trucks.

Still, an error of about 9% existed between the basic quantity of emissions between the number of registered vehicles and the trips for specific vehicle types (RV, van, bus, truck) in the metropolitan area, and the rate of error was the widest in Incheon. Likewise, because the calculation of the basic quantity of vehicle emissions for the number of registered vehicles was not reflected in the actual vehicles' interregional features of travel, there exists the possibility that error may have been included when running the calculation by unit of quantity of emissions by specific region. Accordingly, there is the necessity of considering the trip features by vehicle type as seen in the results of this study in order to realistically calculate the quantity of emissions for mobile road pollutant by unit of region.

Korea is not yet adequately equipped with the infrastructure to collect O/D data of all registered vehicles in the country. Meaning, there are limits to assuming the number of vehicles passing inter-region and intra-region based on the actual transport data that was collected. Therefore, this study estimated the trips based on the number of registered vehicles. However, this study couldn't consider the characteristic of trips such as passing traffic and intra-regional trips. Based on the results above, along with an expansion in the related infrastructure that can collect data based on units of passing vehicles in regional government in order to improve the reliability of the results of calculating the quantity of vehicle emissions by unit of regional government, further ongoing research will have to be conducted in order to overcome the limits presented in this study.

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