IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY
ANALYSIS ON CHARACTERISTICS OF TRAFFIC VOLUME BY TIME AND VEHICLE TYPE ON NATIONAL EXPRESSWAYS

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ABSTRACT
The Statistical Yearbooks of Traffic Volume that have been made by collecting road traffic data annually from national expressways, general highways, and local roads in Korea contain the traffic volume by road class, driving direction, vehicle type, and traffic time. The data contained in the yearbooks is highly utilized in studies on road and traffic fields and is used as foundational data for road planning, design, and operation. This study aims to analyze the current status of the traffic volume surveys, and discuss the characteristics of the data by comparing the traffic volumes with the vehicle type and traffic pattern taking time into consideration to determine the characteristics of the data.

KEYWORDS: freeway, coverage survey, traffic volume, vehicle rate, vehicle type

I. INTRODUCTION
The road traffic volume survey is performed by surveying the number of passing vehicles on the roads in terms of the driving direction, the vehicle type, and the traffic time. The data collected through the survey is published under the name of the Statistical Yearbook of Traffic Volume annually. The yearbooks are utilized widely for road planning, traffic operation, and road repair, and are employed as foundational data to establish traffic planning. The data acquired by the road traffic volume surveys has been recognized as valuable data that can be used frequently for road and traffic fields.

The road traffic volume surveys types can be categorized into permanent surveys performed by machines and coverage surveys carried out by men. In the survey, the road length, the scope, and the priority are taken into consideration for the selection of roads. For the permanent survey, buried-type sensors and fixed survey equipment are installed at specific locations, and the number of passing vehicles at the specific location is measured over a long period of time, enabling them to be recorded in a time series manner. The coverage survey is conducted when the traffic volume is needed on some specific section of a roadway. It is conducted to identify the overall road usage status. The annual average daily traffic (AADT) volume can be measured with the permanent surveys, but the cost is considerably increased, due to the permanent equipment purchase costs, along with operation and maintenance expenses. Thus, the permanent survey is only conducted at major locations, while the coverage survey is more frequently conducted at most locations to collect the basic traffic volume data required for the calculation of AADT, because the cost is relatively lower than that of the permanent survey.

In this study, data from the expressways and national highways in 2017 is utilized to analyze the characteristics of traffic volume in relation to time and the vehicle type that was collected through the coverage survey. The study results of the characteristics of traffic volumes by vehicle type and time are expected to be utilized for improvements on data collection work during coverage surveys and ultimately road design and operation, thereby contributing to efficient work performance and improvements in economic feasibility.

II. MATERIALS AND METHODS
1. Current status overseas
The coverage survey of traffic volume in the USA is generally conducted over a 6.4km section of road on average to measure the traffic volume. The survey is conducted for two days (48 hours) at each location. The survey is conducted every three years. The traffic volume survey and vehicle classification survey are conducted separately. The vehicle classification survey is not conducted over the entire section, but at one or two locations within the section or in major locations, which are selected to classify vehicle types.

Japan has conducted the coverage traffic volume survey every three years as part of the road traffic volume census. The traffic volume survey is conducted over a 7km section of road on average. The survey time is from 7 am to 7 pm, and the survey time is divided into weekdays and weekends. For the major locations, 24-hour daytime and nighttime surveys may be used.

The UK conducts the traffic volume survey using the rotating census method. The survey is conducted every six years at 12,000 locations on the major trunk roads and at 4,000 locations on the non-trunk roads. The traffic volume survey is conducted every year at around 2,000 locations on the highly important roads and other locations are surveyed using the rotating census method. The traffic volume survey is conducted from 7 am to 7 pm after selecting a weekday in the following months: April, May, June, September, and October, which are likely to be less influenced by weather than other months.

France installs fixed traffic volume survey equipment and conducts permanent surveys at 1,000 locations and coverage survey at 270 locations. The coverage survey collects data every hour (for a total of 12 times) in both directions. On the motorways, the survey equipment is installed in every 50 km to survey the traffic volume in the survey locations on the regular basis annually, but the number of permanent traffic volume surveys (permanent survey) is gradually diminishing, whereas the number of the coverage survey locations is expanding. The coverage survey in Germany is conducted eight times in a year if the mean traffic volume is more than 5,000 vehicles, otherwise the survey is conducted six times.

2. Current status in Korea

In Korea, permanent and coverage surveys are conducted differently depending on road class. The traffic volume surveys on expressways are conducted by the Korea Expressway Corporation, which is responsible for the management of expressways in Korea, as do the owners of privately financed expressways. The local governments or city councils conduct the traffic surveys on their local roads. For the general highways, the Korea Institute of Construction Technology (KICT) conducts the surveys. A traffic volume survey is conducted on the expressways and on local roads at a specific date, once a year, for 24 hours, while a traffic volume survey of general highways is conducted one to three times to assess the traffic volume and once to assess the vehicle type classification due to the lack of human survey resources and the large amount of survey locations.

The coverage survey is divided according to the survey location and time: October coverage surveys conducted on expressways and local roads, and coverage surveys conducted on local roads. Table 1 summarizes the data collection agencies and survey methods of the coverage surveys by road classification.

Table 1. Organizations that perform coverage surveys and methods used by road class

road level	data collection agency	traffic survey	vehicle classify survey
expressway	expressway corporation	machinery(AVC/VDS)	manpower
highay	institute of const. Tech.	machinery(NC47)	manpower
local road	local government	manpower	

For the expressways and local roads, the coverage surveys of traffic volume are conducted on the third Thursday in October annually by the Korea Expressway Corporation, private expressway owners, and local governments. In this survey, the traffic volume of 12 vehicle types is surveyed by time and traffic direction from 7:00 to 24:00. Basically, traffic volumes, the time, and the vehicle type are surveyed simultaneously. Since buried equipment and video-assisted traffic volume detectors can be used to collect traffic volume, the survey of the traffic volume by time is conducted by the traffic volume equipment. On the other hand, data of traffic volume by vehicle type is collected by surveyors. For privately financed expressways and highways, various methods are used to survey the traffic volume. The New Airport Highway expressway employs a video analysis method using closed-circuit television (CCTV) video, and the New Daegu-Busan expressway uses a vehicle detection system (VDS) mounted with piezoelectric sensors to conduct the survey. As for the Nonsan–Cheonan expressway, only human surveyors conduct the survey without using traffic volume equipment. The coverage survey is conducted by various methods using equipment and surveyors.

The coverage traffic volume survey for the general highways in Korea is conducted by the KICT. The coverage survey is conducted on normal business days, excluding public holidays, vacation days, or national holidays, which exhibit the characteristics of abnormal traffic volumes. Mainly, business days from March to November are selected to survey the traffic volume, separate surveys of traffic volume only and traffic volume in respect to

vehicle type are conducted. In the coverage survey, survey equipment (NC47 etc.) is used to survey the traffic volume, and mobile survey equipment is installed in each of the lanes from 7 am to 7 am the next day collecting data for all 24 hours, allowing for the assessment of the hourly traffic volume. The survey concerning vehicle type is conducted by counting the number of vehicles by vehicle type by surveyors. The traffic volume by vehicle type is for one to two hours taking into account the driving direction is of the traffic.

Table 2. Number of locations for traffic volume survey per year by road class

road level	2013	2014	2015	2016	2017
expressway	350	385	406	451	478
local road	1,418	1,482	1,475	1,470	1,474
highway(coverage survey)	1,203	1,153	1,157	1,171	1,151
highway(permanent survey)	433	429	422	423	445

Table 2 presents the number of locations of traffic volume surveys per year taking into consideration the road class. For the permanent survey on general highways, fixed survey equipment that can classify the vehicle type is installed to conduct the survey automatically and continuously. On the other hand, coverage surveys are conducted on roads where the performance survey equipment is not installed. The traffic volume data collected by the coverage survey is aggregated hourly for both the daytime and the nighttime, and divided into vehicle types: sedans, buses, small trucks, and large trucks to provide statistical data of the coverage survey. Table 3 presents the integrated criteria to classify 12 type vehicle types, which were set by the Ministry of Land Transport and Traffic, in which vehicles types were classified according to the driving purpose of vehicle (passenger, bus, and cargo), the number of units (one unit, two units), the number of vehicle axles (two to six axles), and the vehicle size.

Table 3. integrated 12 type vehicle classification

car type	detail categorize	unit	zxis	wheel	classification
1	less than 15 person sedan/van	1	2	4	sedan
2	more than 15 person van			6	bus
3	1～2.5ton truck			6	small truck
4	more than 2.5ton truck			6	
5	3axis truck		3	10	medium truck
6	4axis truck		4	12	
7	5axis truck		5	14	
8	4axis semi trailer	2	4	14	large truck
9	4axis full trailer			14	
10	5axis semi trailer		5	18	
11	5axis full trailer			18	
12	6axis semi trailer		6	22	

III.   RESULTS AND DISCUSSION

1. Analysis on vehicle type data on expressways

To compare and analyze the hourly traffic volume by vehicle type, and the hourly traffic volume corresponding to vehicle type compared to the total hourly traffic volume, 12 survey locations on expressways were selected randomly in 2107. Table 4 presents the details of the locations.

Table 4. Analysis locations of hourly traffic volume by vehicle type on the expressways

| Spot No.	road name	road section name	crossroad	length
00107	expressway No.1	gyeongju IC ~ geoncheon IC	4	10.4km
00125	expressway No.1	daejeon IC ~ hoedeok JCT	6	5.9km
00132	expressway No.1	cheonan IC ~ anseong IC	8	20.0km
01002	expressway No.10	suncheon IC ~ kwangyang IC	4	8.8km
01019-3	expressway No.10	bukchanwon IC ~ chanwon JCT	4	3.5km
01516	expressway No.15	kwangcheon IC ~ hongseon IC	4	10.8km
01525	expressway No.15	bibong IC ~ maesong IC	6	4.0km
02515	expressway No.25	cheongeup IC ~ teain IC	4	12.8km
03000-2	expressway No.30	myeoncheon IC ~ kodeok IC	4	8.7km
03004	expressway No.30	boeun IC ~ sokrisan IC	4	6.0km
03532	expressway No.35	konjiam IC ~ kwangju IC	4	12.1km
04507	expressway No.45	kimcheon JCT ~ seonsan IC	4	9.0km

The data collection was conducted based on the coverage survey data on the expressways from 7 am to next day 7 am on Wednesday, October 18, 2017. The hourly traffic volumes and traffic volumes considering the 12 vehicle types were calculated, thereby analyzing the proportion of traffic volume with respect to vehicle type. For the convenience of data analysis, the 12 vehicle types were grouped into only five types of vehicles: sedans (type 1), buses (type 2), small trucks (types 3 and 4), medium-sized trucks (types 5 to 7), and large trucks (types 8 to 12). The trucks were divided into groups according to the number of axles and if the truck was a single unit or a multi-combination truck. A small truck refers to a two-axle truck, a medium-sized truck is three-axle or larger single unit truck, and a large truck refers to a multi-combination truck.

Table 5 presents the daily traffic volume, the proportion of weekly traffic volume, and the proportions of sedan, buses, and small, medium, and large trucks at the analysis target locations. The proportion of traffic volume of each vehicle type refers to the proportion of the daily traffic volume. The analysis results showed that as the location was closer to Gyeonggi-do, the traffic volume was larger. Although there was a slight difference among the locations, the proportions of sedans (59.8%) and small trucks (19.4%) accounted for 79.3% of the traffic volume.

Table 5. Daily traffic volume, weekly proportion, and proportions of traffic volumes
by vehicle type at the survey locations on the expressways

Spot No.	Day Traffic	week rate	sedan	bus	small truck	medium truck	large truck
00107	40,528	72.2	52.3	4.9	19.1	13.4	10.5
00125	85,428	69.4	60.5	3.9	20.4	11.2	4.0
00132	135,105	70.4	67.3	7.6	15.2	7.7	2.2
01002	19,142	76.5	55.7	4.2	19.5	11.4	9.2
01019-3	55,983	72.4	55.0	3.4	20.4	13.5	7.7
01516	27,004	68.0	60.6	2.9	19.7	13.1	3.7
01525	114,855	72.0	63.0	1.7	21.2	10.5	3.6
02515	33,082	72.0	64.8	6.2	19.5	7.9	1.5
03000-2	14,269	75.8	65.2	2.6	16.5	9.9	5.8
03004	25,548	67.4	54.0	4.9	17.9	15.1	8.2
03532	52,338	76.0	65.8	5.8	25.5	2.6	0.3
04507	59,765	64.3	53.1	4.3	18.2	16.1	8.3
average	55,254	71.4	59.8	4.4	19.4	11.0	5.4

Figs. 1 to 5 show the generated chart graphs that indicate the trends of hourly traffic volumes in relation to the vehicle types proportionally from 1:00 to 24:00 at the 12 locations. The trends of hourly fluctuation by vehicle type proportion can be compared across the 12 locations. Fig. 1 shows the traffic volume of sedan group, which reveals different characteristics between daytime and nighttime. In particular, the proportion of the traffic volume of sedan during the nighttime (1:00 to 7:00) was lower than that during the daytime. The values of the daytime and the nighttime were 5.7% and 12.9% respectively, indicating a greater variation in the daytime than that in the nighttime.
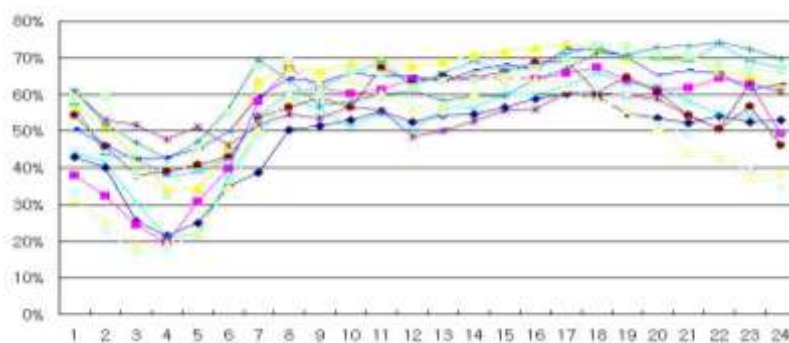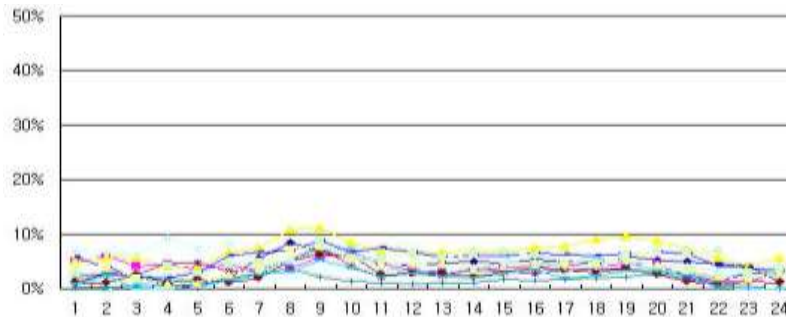

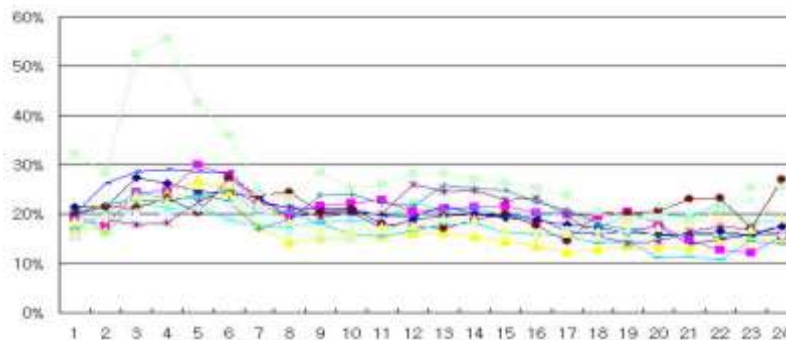*Fig. 1 vehicle rate graph of sedan(1 type)*

Figs. 2 and 3 show the proportions of buses and small trucks of the total traffic volume, respectively. The standard deviation of the proportion of bus was 4.4% in total, 4.6% in the daytime, and 3.7% in the nighttime. The standard deviation of the proportion of small trucks was 2.6% in total, 2.9% in the daytime, and 2.6% in the nighttime. Both of the vehicle groups showed a similar proportion for all hours.

Figs. 4 and 5 exhibit that the standard deviations of the proportions of medium and large trucks during the daytime and the nighttime are 3.0% and 5.6% for medium trucks, and 3.0% and 4.3% for large trucks. Both of the vehicle groups showed a high proportion and a severe variation during nighttime (in particular from 1:00 to 6:00).

RESEARCHERID
THOMSON REUTERS

[Geun-Hyung* *et al.,* 7(8): August, 2018]
IC™ Value: 3.00
ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

This was because the tolls of the expressways for a three-axle or larger trucks are discounted by 50% if the proportion of driving time at night (21:00 to 6:00) was more than 80% of the total driving time.
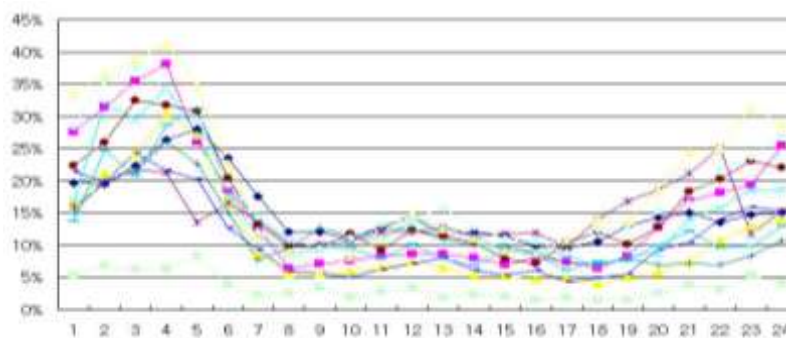

*Fig. 2 vehicle rate graph of medium truck(5-7 type)*

Fig. vehicle rate graph of large truck(8-12 type)

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Fig. vehicle rate graph of medium truck(5-7 type)
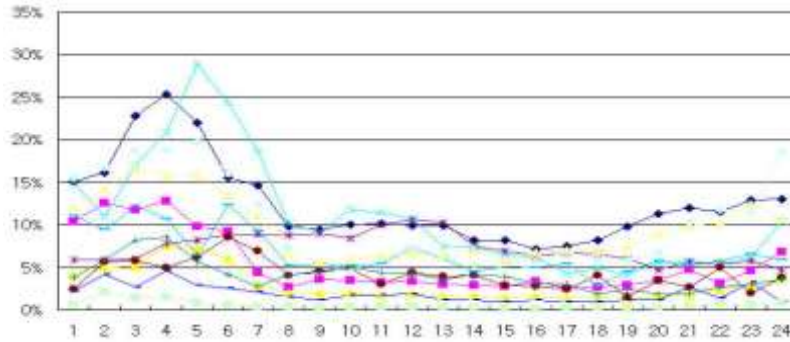
Fig. vehicle rate graph of large truck(8-12 type)

Table 6 presents the above analysis results of traffic volume proportions by vehicle type on expressways. A smaller deviation was revealed during the daytime than during the nighttime in all vehicle types except for sedans. This result indicates that the proportion of sedan decrease, while that of medium and large trucks increase greatly at nighttime. This was due to the nighttime toll discount policy. The buses and small trucks reveal a relatively constant proportion throughout the all hours. Except for some outlying hours, the traffic volume showed a difference of only 3% overall, regardless of the time of day.

table.6 Proportions of daily traffic volume, weekly traffic volume, and traffic volume by vehicle type at the survey locations on the expressways.

type	component ratio average			component ratio deviation		
	days	daytime	night	days	daytime	night
sedan	59.8	62.1	54.7	5.5	4.9	8.6
bus	4.4	4.6	3.7	1.7	1.7	1.7
small truck	19.4	19.4	19.3	2.6	2.9	2.6
medium truck	11.0	9.0	15.8	3.7	3.0	5.6
large truck	5.4	4.9	6.6	3.3	3.0	4.9

2. Analysis on vehicle type data on general highways

The coverage survey on the general highway is conducted by separating the traffic volume survey one to three times between March and November, and the vehicle type classification survey is conducted for one to two hours. A limited number of human resources conduct the coverage survey at the locations distributed around the nation. Table 7 presents the current information concerning the traffic volume survey locations of the general highways as of 2017. It reveals the current status of the coverage survey locations, intelligent transportation system (ITS)-related locations, and coverage survey locations by province (do).

table.7 Current status of the number of locations of traffic volume on general highways by province (do) (as of 2017)

Area(Do)	spot	permanent survey spot	ITS related spot	coverage survey spot
kyeongki	204	71	66	67
kwangwon	187	49	6	132
chungbuk	139	39	17	83
chungnam	174	60	31	83
cheonbuk	190	51	3	136

|				
cheonnam	218	53	10	155
kyeongbuk	264	81	19	164
kyeongnam	220	41	13	166
total	1,596	445	165	986

Coverage surveys were conducted at total of 1,596 locations on general highways, and the vehicle type classification surveys were conducted at 1,151 ITS-related and coverage survey locations, excluding the 445 permanent locations as of 2017. Based on the vehicle type survey data collected in 2017, traffic volumes, proportions of traffic volume by vehicle type, and data collection start times were analyzed. The analyzed results of the surveyed data are depicted in Figs. 6 to 8.
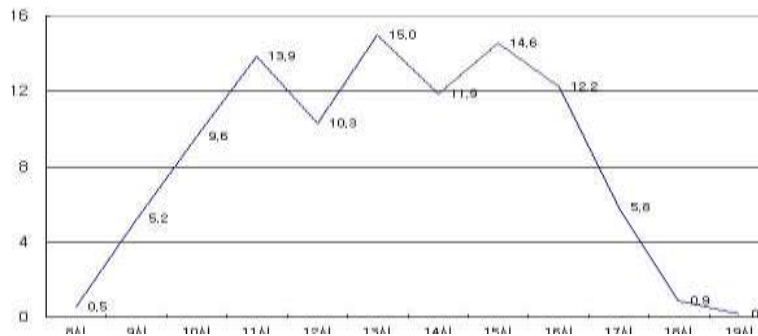
Fig. 6 vehicle rate survey start time in highway
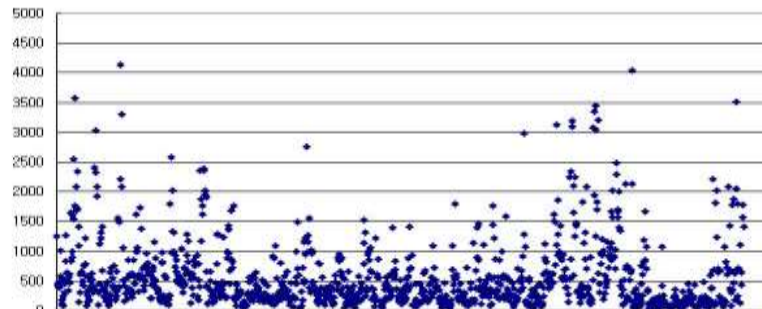
Fig. 7 vehicle rate traffic distribution in highway
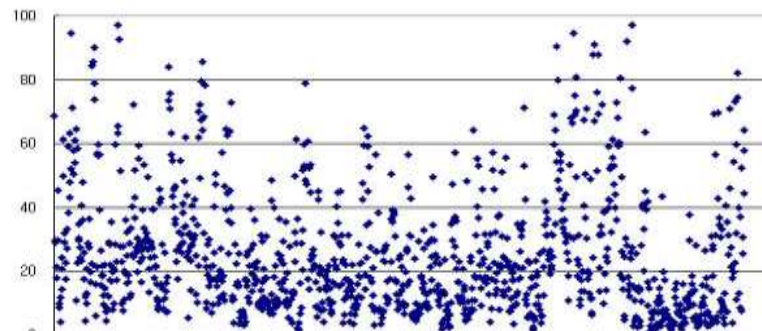
Fig .8 vehicle rate sedan traffic distribution in highway

Fig. 6 shows the start times of the vehicle type classification surveys, which indicate that the surveys were mostly conducted during the daytime, from 9:00 to 18:00. Fig. 7 shows the total traffic volumes measured considering the vehicle type classification survey on the general highways. The calculated mean value of the total passing vehicles was 567 vehicles. Fig. 8 shows the proportion of sedan traffic, which is a typical vehicle type on the highways, out of the total traffic of all vehicles. The calculated mean value was 25.9%. This figure is in contrast with the proportion of sedan traffic on the expressways, which was 50% to 70%.

The vehicle type survey was conducted for only one hour during the coverage survey on general highways, therefore, the hourly characteristics by vehicle type cannot be identified, which was in contrast with the survey conducted on the expressways. In particular, monthly, daily, and hourly comparisons cannot be achieved due to the inconsistencies of survey dates and start times. Thus, it is required to conduct a survey for more than a one-hour duration. More specifically, a trend of traffic volumes by vehicle type should be identified through the vehicle type traffic data collected for at least three hours, and preferably six hours to employ the traffic volumes by vehicle type in the future.

IV.   CONCLUSION

The data obtained from the road traffic volume survey can be usefully employed in road design, road management, road operation, traffic planning, and traffic flow analysis. The current Statistical Yearbooks of Traffic Volume provide daily traffic volumes and daytime and nighttime traffic volumes only. Nonetheless, the daily traffic volume data only are highly helpful in understanding the current status of roads. However, the yearbooks do not provide hourly traffic volumes when considering vehicle types and time. Thus, traffic management based on time is not properly achieved currently.

This study analyzed the hourly fluctuation of traffic volumes by vehicle type obtained through the vehicle type data acquired from the coverage surveys on the expressways and general highways. The analysis results showed that due to the discounted toll charges, the traffic volume of medium and large trucks of more than three-axle was larger at night than during the day, and the traffic volume of buses and small trucks was relatively constant throughout the day while sedans were mostly seen during the daytime. Except for some outlying data, most vehicles, when viewed hourly and by vehicle type, showed a constant proportion of the vehicle traffic, and the total volume showed a standard deviation of less than 3% overall. Since the study results were based on daily data on the third Thursday of October, more effective analysis results of traffic volume by vehicle type would be obtained if more diverse data, such as other months, date, and weekday and weekend was to be obtained. For the general highways, an improvement is needed to enable the analysis of the characteristics of the hourly traffic volume data by vehicle type. This can easily be achieved by extending the duration of vehicle type classification surveys to at least three hours.

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