Prediction of HV Factor in Expressways Using A Short-Term VDS Data

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Nomenclature

q	Flow rate for 1 hour(veh/h/l)
N	No. of vehicles observed for 15 min(veh)
t	A unit time period(15 min)
q_i	Flow rate for each 15 min(veh/15 min/l)
u_s	Mean speed at station(km/h)
u_i	Travel speed for each vehicle i(km/h)
d	Distance between loop detectors at station(m)
$\bar{t}$	Mean travel time(sec)
O	Occupancy(%)
$(t_o)_i$	Time that detector is occupied by $i-th$ vehicle(sec)
K	Hourly volume factor
Q	Hourly volume(veh/h)
AADT	Annual average daily traffic(veh/day)
$\mathrm{K_j}$	Estimate j of hourly volume factor($j=1,3,5,7$)
Q_i	$i-th$ hourly volume for analysis(veh/h)
$\mathrm{ADT_j}$	Average daily traffic for a short-term period j(j=1, 3, 5, and 7 days)(veh/day)
β_j	Regression coefficients(j=0, 1, 2, 3)
r	Correlation coefficients
$(\mathrm{K_{cal}})_\mathrm{i}$	$i-th$ K calculated
$(\mathrm{K_{exp}})_i$	$i-th$ K expected
n	No. of paired samples
t	t statistic of matched pair samples

s_D	Standard deviation of difference in K_{cal} and K_{exp}
$\overline{D}$	Mean of difference in K_{cal} and K_{exp}
D_i	Difference in K_{cal} and K_{exp}

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단기 VDS자료를 이용한 고속도로의 시간교통량계수 추정에 관한 연구

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초록

일반적으로 고속도로란 직진통행차량의 접근만을 허용하도록 함으로써 고속도로 이용자에게 최고수준의 안전성과 효율성을 제공하는 간선국도라 할 수 있다. 그러나 대부분의 고속도로는 고속도로의 통행방향과 시간대에 따라 높은 중 차량의 혼재율과 차량밀도에 의해 종종 교통정체를 겪고 있는 상황이다. 그래서 고속도로의 기본구간에 대한 교통특성연구를 통해 고속도로의 교통체계를 파악할 필요성이 절실히 요구되고 있다.

이를 위해서 본 연구에서는 한국의 대표적인 고속도로인 경부고속도로와 남해고속도로를 대상으로 약 180여개 지점에서 14일 동안의 교통량검지기시스템(vehicle detection system, VDS)자료를 수집하였고, 이를 바탕으로 고속도로의 기본구간에서 시간교통량계수(K)와 단기자료의 시간교통량계수 추정치(K_j)를 K_1(1일 ADT), K_3(3일 ADT), K_5(5일 ADT) 및 K_7(7일 ADT)로 구분하여 분석하였으며, 시간교통량계수(K)와 단기자료의 시간교통량계수 추정치(K_j)사이의 적절한 상관모형을 구축하고자 하였다.

고속도로의 기본구간에 대한 교통특성분석 및 시간교통량계수(K)와 시간교통량계수 추정치(K_j)사이에 모형구축 및 검증을 통해 다음과 같은 결론에 도달할 수 있었다.

첫째, 고속도로 기본구간의 각 방향별 통행특성에서 상당한 차이가 확인되었다. 그러므로 고속도로의 효율성을 개선하기 위해서는 방향별 통행특성에 따른 고속도로관리체계를 구축할 필요가 있다고 판단되었다.

둘째, 고속도로 기본구간의 시간교통량계수(K)와 시간교통량계수 추정치(K_7)사이에 높은 상관특성을 보이는 것으로 나타났다. 그러므로 시간교통량계수와 시간교통량계수 추정치사이에 적절한 상관관계를 검토할 필요가 있다고 판단되었다.

셋째, 고속도로의 시간교통량계수(K)와 시간교통량계수 추정치(K_7)사이에 선형 및 곡선추정 모형들이 높은 상관성을 가지는 것으로 나타났다. 그러므로 시간교통량계수(K)의 수준별 적정모형을 검토할 필요가 있다고 판단되었다.

넷째, 시간교통량계수의 수준별 모형검토에서 파워모형이 높은 결정력을 보이는 것으로 나타났다. 그러므로 파워모형을 대상으로 시간교통량계수(K)와 시간교통량계수 추정치(K_7)사이에 모형의 유효성을 검토할 필요가 있다고 판단되었다.

다섯째, 수준별 시간교통량계수(K)와 시간교통량계수 추정치(K_7)사이의 검증에서 파워모형의 유효성이 있는 것으로 나타났다. 그러므로 파워모형은 고속도로의 시간교통량계수(K)의 순위도 추정에 가장 적합한 모형으로 판단되었다.

Prediction of HV Factor in Expressways Using A Short-Term VDS Data

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Abstract

Generally expressway imply arterial highway that provides users for high levels of safety and efficiency with full control of access only for through traffic in the expressway. However, most of expressways are often experiencing congestion problems caused by highly mixed rate of heavy vehicles and concentration of vehicles depending on the time period and the travel direction in the expressways. So, it is strongly raised to identify the traffic system by traffic characteristic studies in the basic expressway segments.

The purpose of this study was to collect the 14-day vehicle detection system(VDS) data(volume, speed, headway, occupancy, and density, etc.) at about 180 or more stations of major expressways(Gyeongbu and Namhae expressways in Korea), analyze the traffic flow characteristic data, especially hourly volume factor(K) and estimate K_j(K_1, K_3, K_5, and K_7 on the basis of average daily traffic for 1, 3, 5 and 7 days, respectively) calculated in the basic expressway segments, construct the proper regression models between the hourly volume factor and estimate K_j, and finally select the most appropriate model between the calculated and predicted hourly volume factors in the basic expressway segments.

From the traffic characteristic analyses, the analyses of hourly volume factor(K) and estimate K_j, and the development and verification of model in the basic expressway segments, the following conclusions were drawn:

ⅰ) Traffic characteristics appeared to show a considerable difference in the direction of the basic expressway segments. So, it was needed to establish the expressway traffic management system based on the directional traffic characteristics for improving the efficiency of expressway.

ⅱ) Hourly volume factor(K) in the direction of expressways appeared to have a highly positive correlation with estimate K_j(j=1, 3, 5, and 7) for a short-term period. So, it was needed to examine the relationship between hourly volume factor(K) and the estimate K_j for each direction of the expressways.

ⅲ) The highest hourly proportions of K in expressways appeared to show the rural and urban traffic flow characteristics. So, it was needed to classify these hourly proportions of K for in-depth analysis into; $0.06 \leq K < 0.07$, $0.07 \leq K < 0.08$, $0.08 \leq K < 0.09$, $0.09 \leq K < 0.10$, $0.10 \leq K < 0.11$, $0.11 \leq K < 0.12$, $0.12 \leq K < 0.13$, $0.13 \leq K < 0.14$, and $0.14 \leq K < 0.15$.

ⅳ) Linear, quadratic, cubic and power models appeared to have a highly correlation coefficient(r) between hourly volume factor(K) and estimate K_j(j=1, 3, 5, 7) for each range of interval. So, it was needed to select the proper model in predicting the hourly volume factor(K) with a high explanatory power(R^2).

ⅴ) Power model appeared to be very appropriate in predicting the hourly volume factor(K) by estimate K_7 with a high explanatory power(R^2) and validity for all ranges of interval. So, it was needed to verify the power model between the hourly volume factor(K) and estimate K_7 for a short-term period.

ⅵ) Model verification results appeared to show the high correlation coefficients(r) in the power model with estimate K_7 and fall inside Accept region for all ranges of interval. So, it was needed to determine the power model as the most appropriate one for predicting K in expressways showing the rural and urban traffic flow characteristics.

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1. Introduction

1.1 Background

Generally expressways are divided into rural and urban expressways as the exclusive motorways, and also defined as the highest grade of arterial highways with medians and two lanes or more in one direction and with full control of access which the vehicles using the roads are allowed to enter the mainline segments through the ramps(KHCM, 2005).

As expected from the functions of expressways, rural expressways contribute to the improvement of mobility and accessibility in personal transportation means as well as the increase of transporting capability in cargo transportation ones as major inter-regional connected public roads regardless of the peak-periods, whereas urban expressways do to the improvement of greater mobility and accessibility in personal transportation means than the increase of transporting capability in cargo transportation ones as primary intra-regional connected public roads during the peak-periods.

In addition to the improvement of living standards and the expansion of activity area along with the development of national economy, most of the expressways are, however, suffering from the transportation problems caused by the increased vehicles in expressways. And the limitations must be faced in solving the transportation problems on expressways, because enormous national budget and a long period of time are needed to newly construct, expand, or widen the expressways. Even if newly expressways are constructed by the enormous national budget, they will attract another travel demand caused by the development of the areas adjacent to the expressway and used to suffer from the transportation problem. And so, it is absolutely needed to improve the efficiency of the existing expressways instead of building new ones with the national transportation policies focused on the construction and expansion of transportation facilities and at the same time the appropriate intelligent transportation systems(ITS) such as advanced traveler information systems and advanced traveler management systems (ATIS/ATMS) established for reducing and distributing traffic vehicles concentrated on the expressways(Shin, 2013, Cho, 2012, Kim et al., 2010).

Therefore, this study is to suggest how to find the estimate of hourly volume factor for a short-term period instead of hourly volume factor in the selection of an appropriate period on the existing rural expressways in Korea as shown in **Figure 1.1**.

1.2 Objective

Expressways, which often have the considerable constraints in speed limit, grade, width, and length due to the limits of land use, medians, interchange and design speed of 80km/h or higher in the rural areas, used to suffer from the operational transportation problems by such the travel characteristics as more travel demand and longer travel length when compared to the arterial highways.

So, the purpose in this study is to investigate the traffic flow characteristics including hourly volume factor(K) and the estimates of hourly volume factor for a short-term period of 14 days on the Namhae(Ex-10) and Gyeongbu(Ex-1) expressways under the study, identify the appropriate correlation characteristics between hourly volume factor and the estimates of hourly volume factor for a short-term period, construct the most appropriate regression model for predicting hourly volume factor using the estimate of hourly volume factor, and finally suggest the plan for predicting hourly volume factor using the estimate of hourly volume factor for a short-term period on rural expressways.

Figure 1.1 Expressways under the study

1.3 Process of study

The process for coming to purposes of study is based on the following step-by-step process.

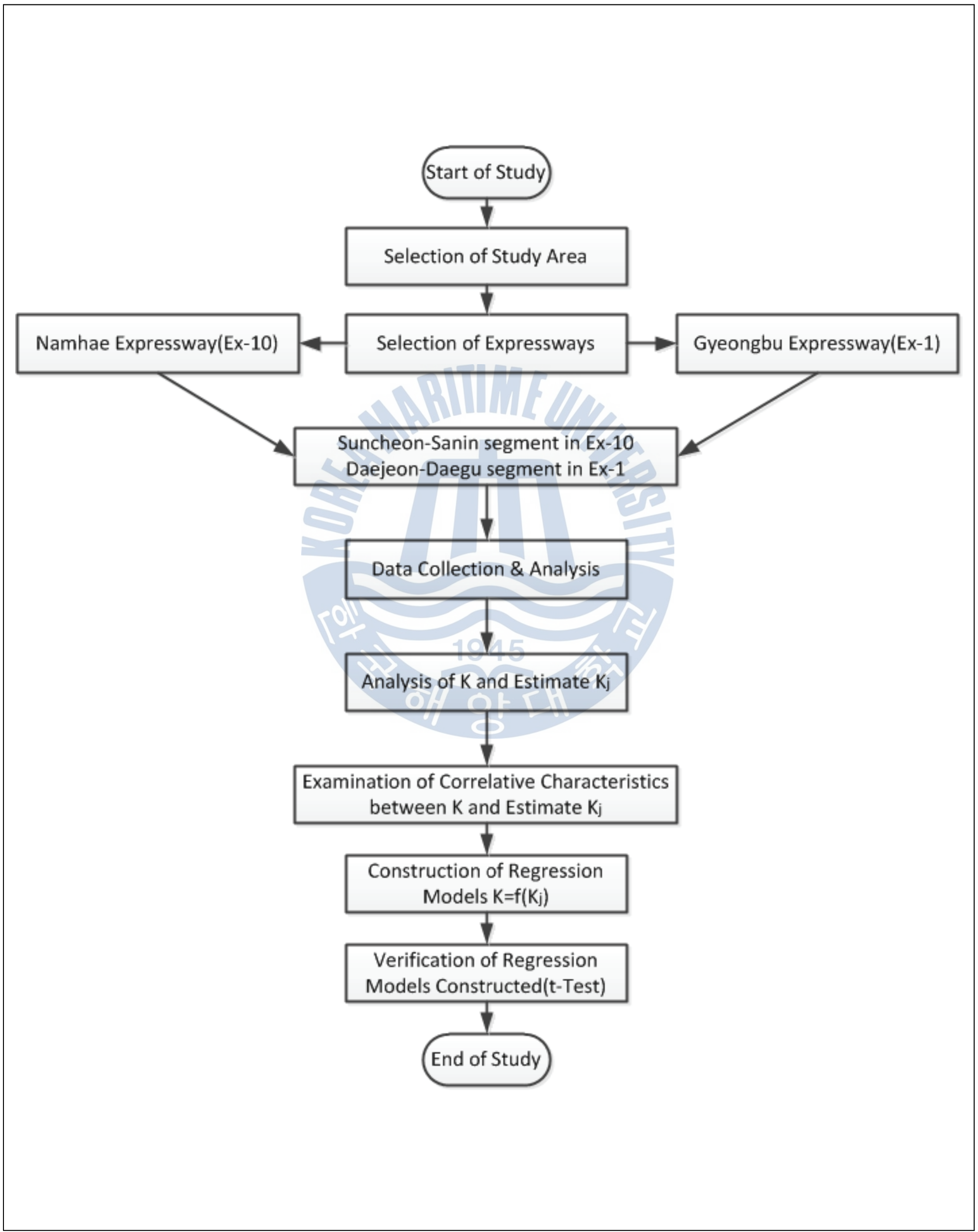


Figure 1.2 Process of study

2. Literature Review

2.1 Reviews from abroad

In the US Highway Capacity Manual(2000), 'Capacity and other traffic analyses focus on the peak hour of traffic volume, because it represents the most critical period for operations and has the highest capacity requirements. The peak-hour volume, however, is not a constant value from day to day or from season to season. If the highest hourly volumes for a given location were listed in descending order, a large variation in the data would be observed, depending on the type of facility. Rural and recreational routes often show a wide variation in peak-hour volumes. Several extremely high volumes occur on a few selected weekends or in other peak periods, and traffic during the rest of the year is at much lower volumes, even during the peak hour. Urban streets, on the other hand, show less variation in peak-hour traffic. Most users are daily commuters or frequent users, and occasional and special event traffic are at a minimum. Furthermore, many urban routes are filled to capacity during each peak hour, and variation is therefore severely constrained. **Figure 2.1** shows hourly volume relationships measured on a variety of highway types in Minnesota. Recreational facilities shows the widest variation in peak-hour traffic. Their values range from 30 percent of annual average daily traffic(AADT) in the highest hour of the year to about 15.3 percent of AADT in the 200th-highest hour of the year and 8,3 percent in the 1,000th-highest hour of the year. Main rural facilities also display a wide variation. The highest hour comprises 17.9 percent of the AADT, decreasing to 10 percent in the 100th-highest hour and 6.9 percent in the 1,000th-highest hour. Urban radial and circumferential facilities show far less variation. The range in percent of AADT covers a narrow band, from approximately 11.5 percent from the highest hour to 7 to 8 percent for the 1,000th-highest hour. **Figure 2.1** is based on all hours, not just peak hours of each day, and shows only the highest 1,100hours of the year.'

The selection of an appropriate hour for planning, design, and operational purposes is a compromise between providing an adequate level of service(LOS) for every(or almost every) hour of the year and economic efficiency. Customary practice in the United States is to base rural highway design on an hour between the 30th- and the 100th-highest hour of the year. This range generally encompasses the knee of the curve(the area in which the slope of the curve changes from sharp to flat). For rural highways, the knee has often been assumed to occur at the 30th-highest hour, which is often used as the basis for estimates of design-hour volume. For urban roadways, a design hour for the repetitive weekday peak periods is common. Studies by Crabtree and Deacon, and Werner and Willis has emphasized the difficulty in locating a distinct knee on hourly volume curves. These curves illustrate the point that arbitrary selection of an analysis hour between the 30th- and 100th-highest hours is not a rigid criterion and indicate the need for local data on which to base informed judgements(TRB, 2000).

The selection of analysis hour must consider the impact on design and operations of higher-volume hours that are not accommodated. The recreational access route curve of **Figure 2.1** shows that the highest hours of the year have more than twice the volume of the 100th hour, whereas the highest hours of an urban radial route are only about 15 percent higher than the volume in the 100th hour. Use of a design criterion set at the 100th hour would create substantial congestion on a recreational access route during the highest-volume hours but would have less effect on urban facility. Another consideration is the LOS objective. A route designed to operate at LOS B can absorb larger amounts of additional traffic than a route designed to operate at LOS D during those hours of the year with higher volumes than the design hour. As a general guide, the most repetitive peak volumes may be used for the design of new or upgraded facilities. The LOS during higher-volume periods should then be tested as to the acceptability of the resulting traffic conditions. The proportion of AADT occurring in the analysis hour is referred to K-factor, expressed as a decimal fraction : The K-factor generally decreases as the AADT on a highway increases ; The reduction rate for high K-factors is faster than that for lower values ; The K-factor decreases as development density increases ; and The highest K-factors generally occur on recreational facilities, followed by rural, suburban, and urban facilities, in descending order. The K-factor should be determined, if possible, from local data for similar facilities with similar demand characteristics(TRB, 2000).

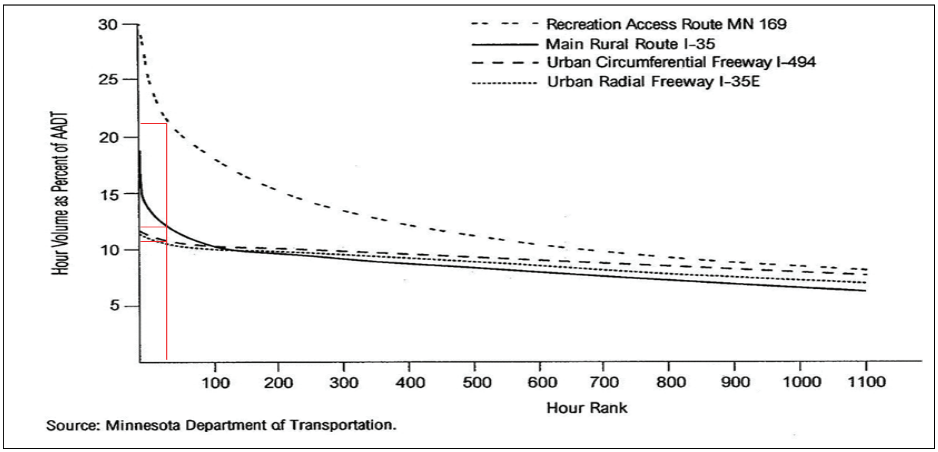


Figure 2.1 Ranked hourly volumes(Source: HCM2000)

In US American Association of State Highway and Transportation Officials(2001), 'The traffic pattern on any highway shows considerable variation in traffic volumes during the various hours of the day and in hourly volumes throughout the year. A key design decision involves determining which of these hourly traffic volumes should be used as the basis for design. While it would be wasteful to predicate the design on the maximum peak-hour traffic that occurs during the year, the use of the average hourly traffic would result in an inadequate design. The hourly traffic volume used in design should not be exceeded very often or by very much. On the other hand, it should not be so high that traffic would rarely be sufficient to make full use of the resulting facility. One guide in determining the hourly traffic volume that is best suited for use in design is a curve showing variation in hourly traffic volumes during the year. Figure 2.2 shows the relationship between the highest hourly volumes and ADT on rural arterials. This figure was produced from an analysis of traffic count data covering a wide range of volumes and geographic conditions. The curves in the chart were prepared by arranging all of the magnitude. The middle curve is the average for all locations studied and represents a highway with average fluctuation in traffic flow. Based on a review of these curves, it is recommended that the hourly traffic volume that should generally be used in design is the 30th highest hourly volume of the year, abbreviated as 30 HV. The reasonableness of 30 HV as a design control is indicated by the changes that result from choosing a somewhat higher or lower volume.'

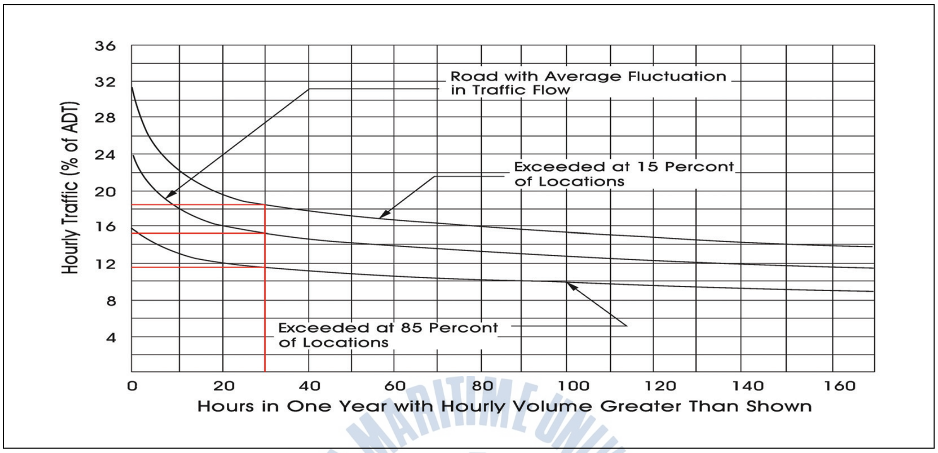


Figure 2.2 Relation between peak hour and ADT volumes on rural arterials(Source: AASHTO)

The curve in Figure 2.2 steepens quickly to the left of the point showing the 30th highest hour volume and indicates only a few more hours with higher volumes. The curve flattens to the right of the 30th highest hour and indicates many hours in which the volume is not much less than the 30 HV. On rural roads with average fluctuation in traffic flow, the 30 HV is typically about 15 percent of the ADT. Whether or not this hourly volume is too low to be appropriate for design can be judged by the 29 hours during the year when it is exceeded. The maximum hourly volume, which is approximately 25 percent of the ADT on the graph, exceeds 30 HV by about 67 percent. Whether the 30 HV is too high for practical economy in design can be judged by the trend in the hourly volumes lower than the 30th highest hour. The middle curve in Figure 2.2 indicates that the traffic volume exceeds 11.5 percent of the ADT during 170 hours of the year. The lowest of this range of hourly volumes is about 23 percent less than the 30 HV. Another fortunate characteristics of 30 HV is that, as a percentage of ADT, it generally varies only slightly from year to year even though the ADT may change substantially. Increased ADT generally results in a slight decrease in the percentage of ADT during the 30 HV. Thus, the percentage of ADT used for determining the 30HV from current traffic data for a given facility can generally be used with confidence in computing the 30 HV from an ADT volume determined for some future year. This consistency between current and future may not apply where there is a radical change in the use of the land area served by the highway. In cases where the character and magnitude of future development can be foreseen, the relation of 30 HV to ADT may be based on experience with other highways serving areas with similar land-use characteristics(AASHTO, 2001).

The design hourly volume(DHV) is the projected hourly volume that is used for design. This volume is usually taken as a percentage of expected ADT on the highway. Figure 2.2 shows the relationship between traffic hourly volumes as a percentage of ADT and the number of hours in one year with higher volumes. This relationship was computed from the analysis of traffic count data over a wide range of volumes and geographic conditions. Figure 2.2 shows, for example, that an hourly volume equal to 12 percent of the ADT is exceeded as 85 percent of locations during 20 hours in the entire year. A close examination of this curve also shows that between 0 and about 25 highest hours, a small increase in the number of hours results in a significant reduction in the percentage of ADT, whereas a relatively large increase in number of hours at the right of the 30th highest hour results in only a slight decrease in the percentage of ADT. This characteristic of the curve has led to the conclusion that it will be uneconomical to select DHV greater than which will be exceeded during only 29 hours in a year. The 30th highest hourly volume is therefore usually selected as the DHV. Experience has also shown that the 30th highest hourly volume as a percentage of ADT varies only slightly from year to year, even when significant changes of ADT occur. It has also been shown that, excluding rural highways with unusually high or low fluctuation in traffic volume, the 30th highest hourly volume for rural highways is usually between 12 percent and 18 percent of the ADT, with the average being 15 percent(AASHTO, 2001).

Note, however, that the 30th highest hourly volume should not be indiscriminately used as the DHV, particularly on highways with unusual or high seasonal traffic(AADT) represented by the 30th highest hourly volume on such highways may not be significantly different from those on most rural roads, this criterion may not be applicable, since the seasonal fluctuation results in a high percentage of high-volume hours and low percentage of low-volume hours. For example, economic consideration may not permit the design to be carried out for the 30th highest hourly volume, but at the same time, the design should not be such that severe congestion occurs during peak hours. A compromise is to select a DHV that will result in traffic operating at a somewhat slightly lower level of service than that which normally exists on rural roads with normal fluctuations. It is therefore suggested that for this type of rural road, it is desirable to select 50 percent of the volume that occurs for only a few peak hours during the design year as the DHV, even though this may not be equal to the 30th highest hourly volume. This may result in some congestion during the peak hour, but the capacity of the highway will normally not be exceeded(AASHTO, 2001).

Particularly Garber and Hoel(1988) mentioned that 'The 30th highest hourly volume may also be used as the DHV for urban highways. It is usually determined by applying between 8 percent and 12 percent to the ADT. Other relations may, however, be used for highways with seasonal fluctuation in traffic flow much different from that on rural roads. One alternative is to use the average of the highest afternoon peak hour volume for each week in the year as the DHV.'

Also, Walker(2004) mentioned that 'Within the past two decades, highway officials adopted the policy of designing highways to meet the traffic load of the 30th highest hourly volume of the year for which the facility was being built. The present analysis of automatic traffic recorder data for rural highways reveals that the 30th-hour factor exhibits a tendency to decline slightly with the passing of time, rather than to remain stable as past studies have indicated. Records for 160 traffic recorder stations in continuous operation from 1946 through 1953 provided the basic data for the analysis. All classes of rural highways were represented and the coverage included 26 states. The average factor for these stations declined at the average rate of 0.11 per year over the period 1946-1953, but a wide variation in the rate of decline was found among different stations. Generally speaking, roads with volumes of more than 3,000 vehicles per day experienced a more rapid rate of decline in the factor than the roads with lesser traffic volumes. Also, 30th-hour factor of 15 or greater experienced a more rapid rate of decline than factors smaller than 15.'

In addition, Crownover(2006) mentioned that 'An automatic traffic recorder(ATR), counting year-round, is the only location where a true K-30 is measured. To determine if short-term counts produced reasonable estimates of the K-30, data was used from fifty-seven ATRs that no more than five days of data missing from the entire year. To simulate the short-term counts, samples were taken from the data. Then ADT, high hour, and K factor were determined. For instance, to simulate a 48-hour count such as Oregon collects, data from 11 AM Tuesday to 11 AM Thursday could be used. The 48 hourly volumes would be summed, then the sum divided by two to produce an ADT. The high hour would be chosen. The ratio of high hour to the ADT is the K factor estimate. The consistency of that statistic throughout the year at any particular station is impressive. The high hours tend to rise and fall with roughly the same seasonality as the volumes. The K factor estimates were produced for six methodologies: three counting styles(48-hour weekday counts, 72-hour weekday counts, and seven-day counts) and two ADT styles(the ADT from the short-term count and the AADT from the station). The greatest success used seven-day counts. Even this method is also not a common practice because tubes would have a tough time staying in place for that long time. The results using the count ADT were amazingly consistent throughout the count season. They did not match the K-30 well, but repeated the statistic well. This makes sense in terms of the high hours rising and falling in roughly the same pattern as the rise and fall of the total ADT.'

2.2 Reviews from Korea

In the Korea Road Design Standards(2005), 'Design hourly factor is the proportion(percentage) to the annual average daily traffic(AADT) of design hourly volume, and this factor is a value to determine which amount of the daily traffic volumes is used as the hourly volume. Design hourly volume is generally determined by the hourly traffic volume at the point which the slope sharply changes by arranging the hourly traffic volumes presented from the permanent traffic counts for a year on the target road for a descending order, and by connecting the points which each hourly traffic volume represents with a gentle curve. And design hourly factor is the proportion divided by the AADT for the hourly volume at the point that the slope sharply changes.'

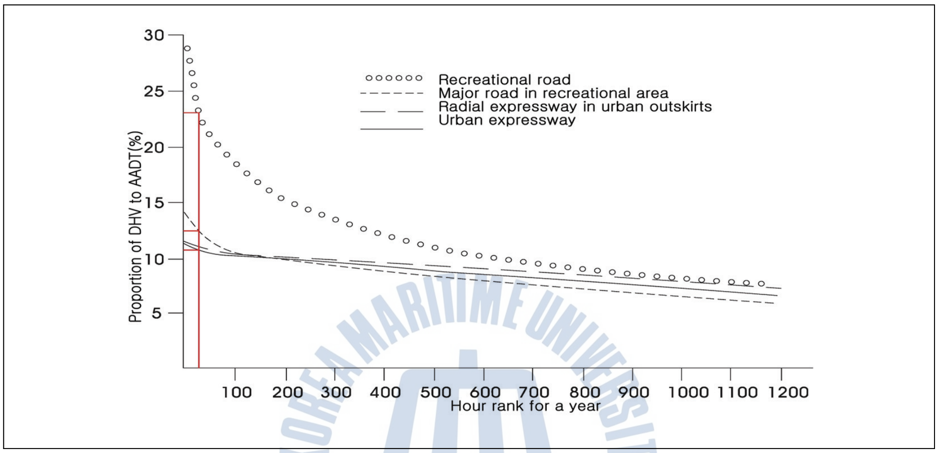


Figure 2.3 Ranked hourly volumes(Source: MLTM)

In the Korea Rules on Road Structure and Facility Standards(2008), 'The 30th design hourly factor decreases with the increase of the AADT on the target road and it also decreases with the increase of the development in the area adjacent to road, whereas traffic volume severely varies with the increase of the 30th design hourly factor. The 30th design hourly factor on the recreational road shows up the highest value, but it shows up the lowest ones in order of rural road, urban radial road and urban road as shown **Figure 2.3**.'

Particularly, Oh et al.(2007) mentioned that 'The detailed criteria and characteristic analyses were made in applying the appropriate design hourly factor and in determining the number of lanes for highway design. The design hourly factor was analyzed depending on the hourly variation through regression model using the 8-year hourly volumes and the AADTs collected at the automatic traffic recorder(ATR) of 93 highways in Korea. And the linear regression model that has no constant was built by using the 30th hourly volume as independent variable and the AADT as the independent variable. Especially the linear model appeared to be in a higher explanatory power and in a less error with classification of the number of lanes between 2 lanes and 4 lanes, and the range of the AADTs: 3 groups. As a result of time-series analysis for design hourly factor, design hourly factor appeared to be no difference with the yearly variation, and appeared to be smaller with more traffic volumes or lanes under the assumption that the existing 30th or 100th design hourly factor would be consistent. However, it was needed to suggest the most appropriate design hourly factor that could reflect more recreational travel demand or the regional characteristics of roads due to the extensive implementation of five-day working system.'

Also, Baik et al.(2007) mentioned that 'Regular traffic count(RTC) data in Korea appeared not to properly reflect the actual hourly volume characteristics analyzing the design hourly factor of expressway with the hourly volumes for the year in West coast expressway. Particularly average design hourly factors appeared to be different from those suggested in existing guidelines and studies, and average design hourly factor on urban roads appeared to be higher than those on rural roads unlike the existing guidelines. The VDS data proved to be needed for better estimation of design hourly factor instead of the RTC data.'

In addition, Ha and Kim(2008) mentioned that 'As a result of predicting the design hourly volume with the correlation analysis and regression analysis using the design hourly factor as the dependent variable, and using the coefficient of variance and the standard deviation in hourly traffic volume, the proportion of heavy vehicles for identifying peak-hour traffic volume and road characteristics, the proportion of day and night, the AADT, the directional split, etc. as the independent variables, curve regression model appeared to be more appropriate than linear regression one. And logarithmic model especially appeared to show the highest explanatory power with the AADT as the independent variable.'

And Jin(2010) mentioned that 'The systematic estimation for inflection point was suggested by the ranked curve model instead of the uniform 30th ranked hour volume for figuring out the design hourly factors on the expressway routes and segments.

Particularly ranked curve model was determined by the higher explanatory variable between power and logarithmic models, and appeared to show a difference of about 0.0192 in mean and about 0.0204 in standard deviation between the 30th design hour factor and the inflection point K. The 30th design hourly factor appeared not to be equal to the inflection point K based on the results of t-Test, and also appeared to be needed to calculate the number of lanes by applying the segment-based design hourly factor instead of the average design hourly factor on the expressway route for the prevention against under- or over-design.'

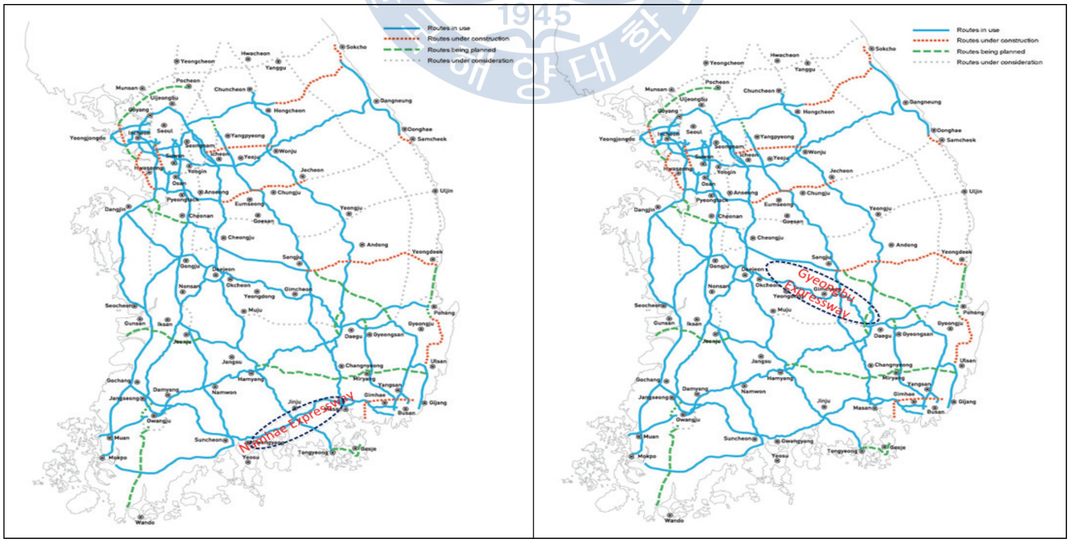
Finally, Kang(2011) mentioned that 'As a result of drawing the ranked hourly volume curves by the existing DHV estimation method and comparing them with the traditional ranked hourly volume curve on both urban and rural expressways, the ranked hourly volumes appeared to be surprisingly lower than those expected on the weekend and the holidays such as Lunar New Year and Chuseok that traffic congestion occurred. The new DHV estimation method that the ranked hourly volume characteristics in the congested weekend and holidays could be taken into consideration instead of the existing one was needed.'

Until now, most of the reviews in the above were focused on the analysis and estimation of design hourly factor on urban and rural expressways, but there were no studies about the regression model between the hourly volume factor and the estimates of hourly volume factor for a short-term period on rural expressways. Therefore, it is going to suggest the most appropriate regression models for predicting the hourly volume factor on the basis of correlation characteristics between the hourly factor and the estimates of hourly volume factor for a short-term period on rural expressways in this study.

3. Data Collection and Analysis

3.1 Data collection

Expressways under the study are major expressways having 4 to 8 lanes from Yeongam in the west to Busan in the east in the Namhae expressway(Ex-10) and from Seoul in the north to Busan in the south in the Gyeongbu expressway(Ex-1) with the speed limit of 100 km/h in Korea as shown in **Figure 3.1**. And data were collected by vehicle detection system(VDS) at the basic segments in Namhae expressway and in Gyeongbu expressway for the study; 4 to 8 lane basic segments in the length of 112.9km from Suncheon to Sanin in Namhae expressway and in the length of 149.8km from Daejeon to Daegu in Gyeongbu expressway as summarized in **Table 3.1**.



Source: Korea Expressway Corporation

Figure 3.1 Basic expressway segments under the study

Table 3.1 Geometry of basic expressway segments under the study

Expressway	Ex-10		Ex-1	
	Total	Segment	Total	Segment
Length(km)	273.1	112.9	416.0	149.8
Number of lanes	4 to 8	4 to 8	4 to 10	4 to 8
Lane width(m)	3.5	3.5	3.5	3.5
Speed limit(km/h)	100	100	100	100

Table 3.2 10 stations selected for analyses(km)

Station	Ex-10	Ex-1
	km point from the west	km point from the south
Station 1	74.90	134.50
Station 2	76.80	136.50
Station 3	83.70	144.11
Station 4	90.55	147.54
Station 5	92.60	155.02
Station 6	94.60	158.46
Station 7	96.20	167.95
Station 8	98.80	169.81
Station 9	100.40	177.62
Station 10	102.20	179.53

Also, data collection was conducted at 95 stations in Namhae expressway and 92 stations in Gyeongbu expressway from 00:00 to 24:00 for 2 weeks (June 19 to July 3, 2012), respectively. And a master dataset was generated every 15 minutes on the basic expressway segments under the study. It was converted into data formats for visual and statistical inspection via a spread sheet, and 10 stations in each direction selected for characteristic analyses as summarized in **Table 3.2**.

3.2 Data analysis

For the microscopic analyses of traffic characteristic data at the sample stations selected, flow was converted into the flow rate (veh/h/l), speed was converted into the station mean speed(km/h) on the basic segments, and occupancy was converted into the percent of the time(%) of the loop detectors occupied as a surrogate for density.

3.2.1 Flow

Flow, as a number of vehicles observed for a unit period, was converted into the hourly flow rate as follows(TRB, 1975);

$$q_i = \frac{N}{t} \tag{1}$$

$$q = \sum_{i=1}^{4} q_i \tag{2}$$

Where, N : no. of vehicles observed for 15 min(veh)

t : a unit time period(15min)

q_i : flow rate for each 15 min(veh/15 min/l)

q : flow rate for 1 hour(veh/h/l)

Flow distribution appeared to be hardly a big difference between the stations in the same direction for 2 weeks, but to be a clear difference between the directions in expressway for 2 weeks as shown in **Figures 3.2~3.5**.

On the one hand, flow analyses appeared to have no big difference with the different peak-period characteristics for each direction in Namhae expressway as summarized in **Table 3.3** and as shown in **Figures 3.6~3.7**. In the eastbound(EB) direction of Namhae expressway, the average flow rate appeared to be about 310veh/h/l to about 320veh/h/l. And the minimum flow rate appeared to be about 40veh/h/l showing a decrease of about 87% when compared with the average flow rate in the same direction, but the maximum flow rate appeared to be about 590veh/h/l to about 630veh/h/l showing a increase of about 92% when compared with the average flow rate in the same direction. Also the peak-period flow rate appeared to be a slight difference with the maximum flow rate in the EB direction for the afternoon peak-period(PM-Peak). In the westbound(WB) direction of Namhae expressway, the average flow rate also appeared to be about 310veh/h/l to about 320veh/h/l in the same direction. And the minimum flow rate appeared to be about 40veh/h/l to 50veh/h/l showing a decrease of about 86% when compared with the average flow rate in the same direction, but the maximum flow rate appeared to be about 580veh/h/l to about 590veh/h/l showing a increase of about 85% when compared with the average flow rate in the same direction. Also the peak-period flow rate appeared to be almost consistent with the maximum flow rate in the WB direction for the morning peak-period(AM-Peak) unlike the EB direction.

On the other hand, flow analyses appeared to have a considerable difference with the different peak-period characteristics for each direction in Gyeongbu expressway as summarized in **Table 3.4** and as shown in **Figures 3.8~3.9**. In the northbound(NB) direction of Gyeongbu expressway, the average flow rate appeared to be about

370veh/h/l to about 590veh/h/l. And the minimum flow rate appeared to be about 90veh/h/l to 110veh/h/l showing a decrease of about 78% when compared with the average flow rate in the same direction, but the maximum flow rate appeared to be about 580veh/h/l to about 970veh/h/l showing a increase of about 55% when compared with the average flow rate in the same direction. Also the peak-period flow rate appeared to be almost consistent with the maximum flow rate in the NB direction for the morning peak-period(AM-Peak). In the southbound(SB) direction of Gyeongbu expressway, the average flow rate also appeared to be about 380veh/h/l to about 580veh/h/l. And the minimum flow rate appeared to be about 110veh/h/l to 130veh/h/l showing a decrease of about 74% when compared with the average flow rate in the same direction, but the maximum flow rate appeared to be about 670veh/h/l to about 1,120veh/h/l showing a increase of about 85% when compared with the average flow rate in the same direction. Also the peak-period flow rate appeared to be almost consistent with the maximum flow rate in the SB direction of the afternoon peak-period(PM-Peak) unlike the NB direction.

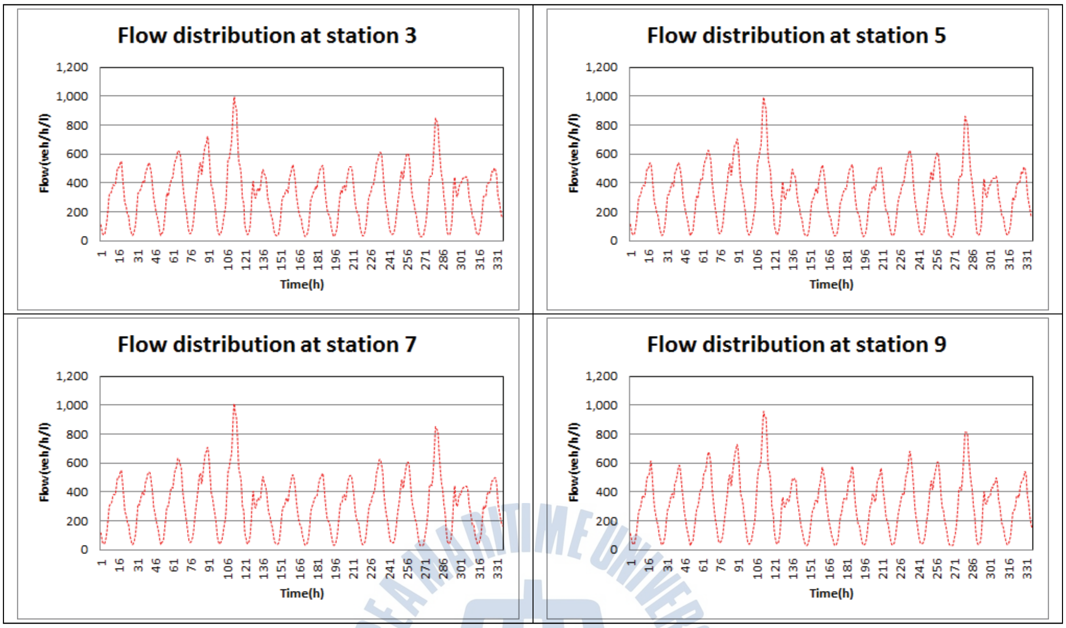


Figure 3.2 Flow distribution of expressway Ex-10(EB)

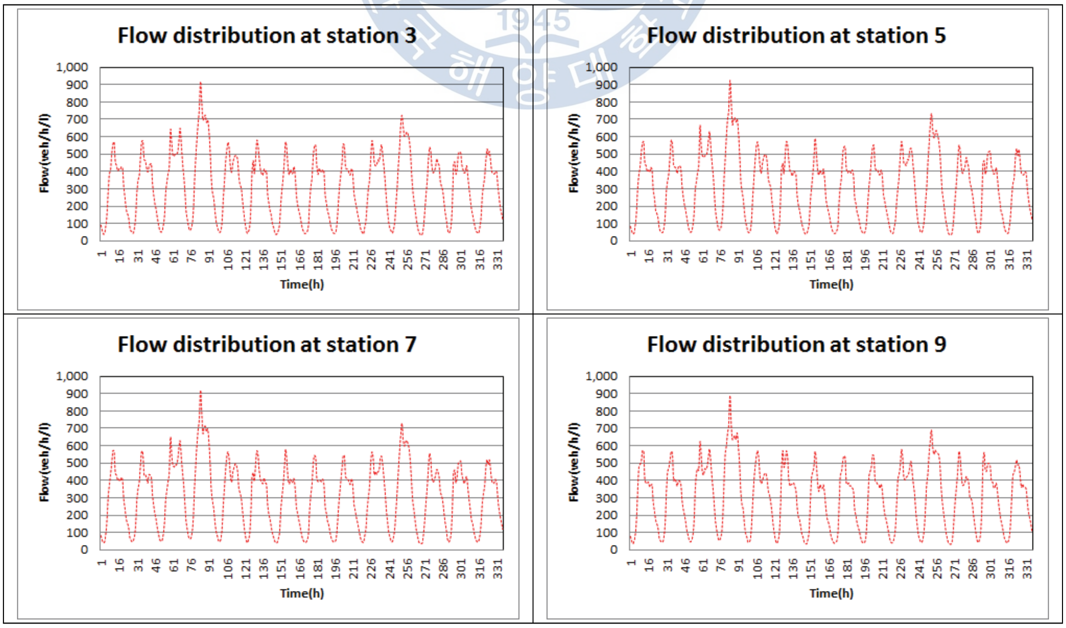


Figure 3.3 Flow distribution of expressway Ex-10(WB)

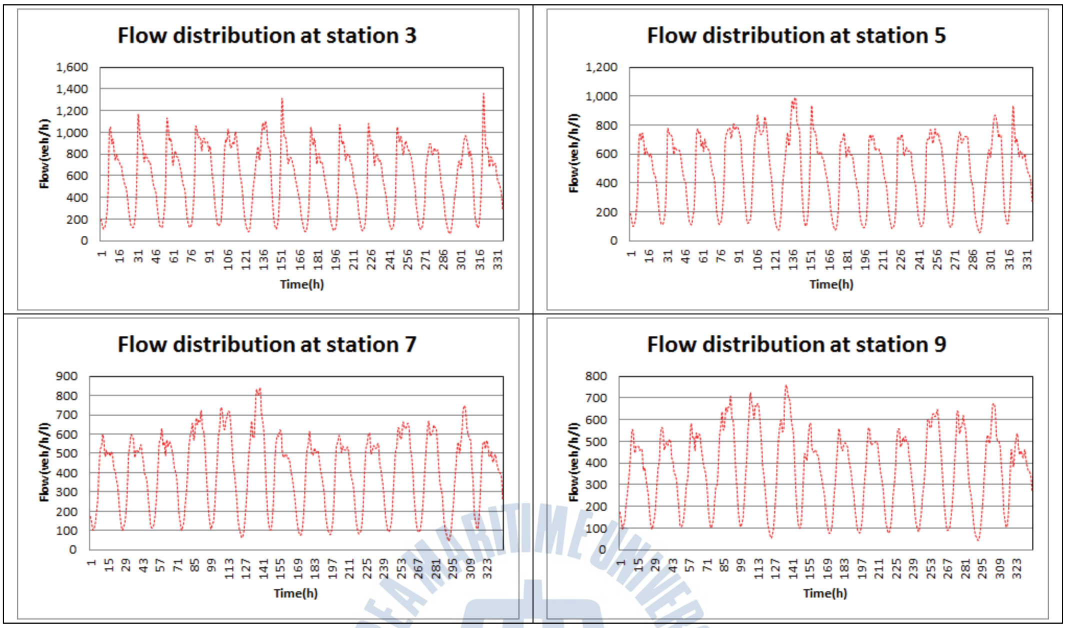


Figure 3.4 Flow distribution of expressway Ex-1(NB)

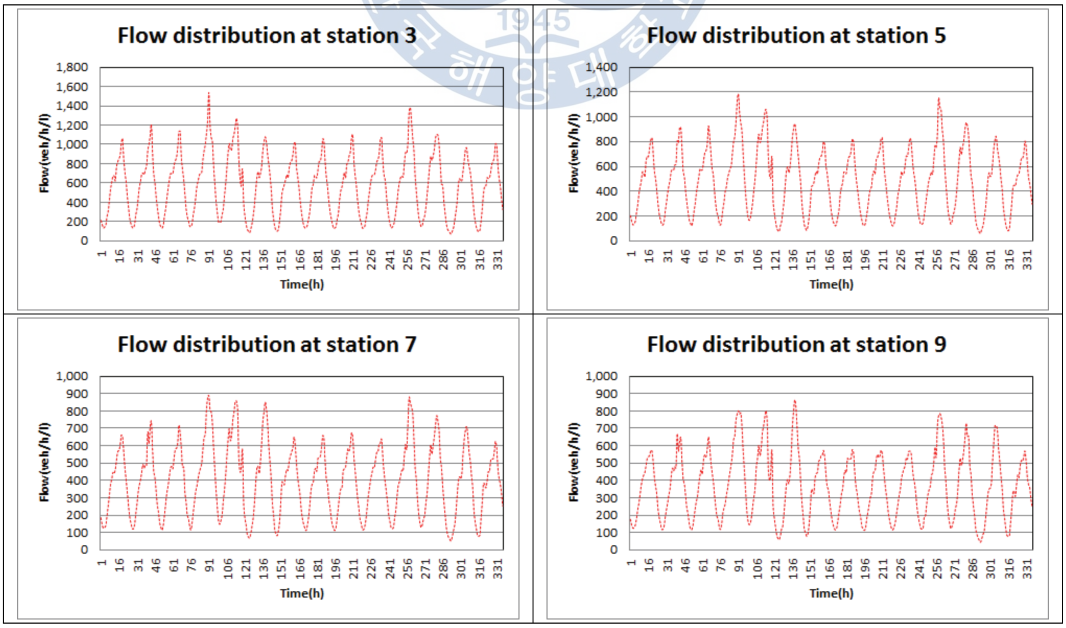


Figure 3.5 Flow distribution of expressway Ex-1(SB)

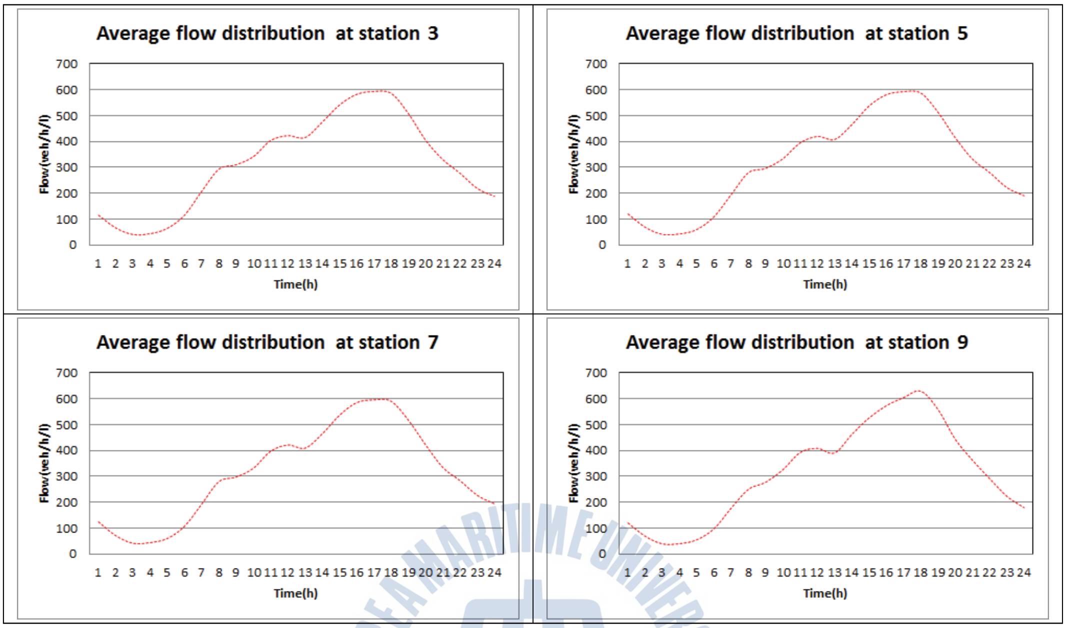


Figure 3.6 Average flow distribution of expressway Ex-10(EB)

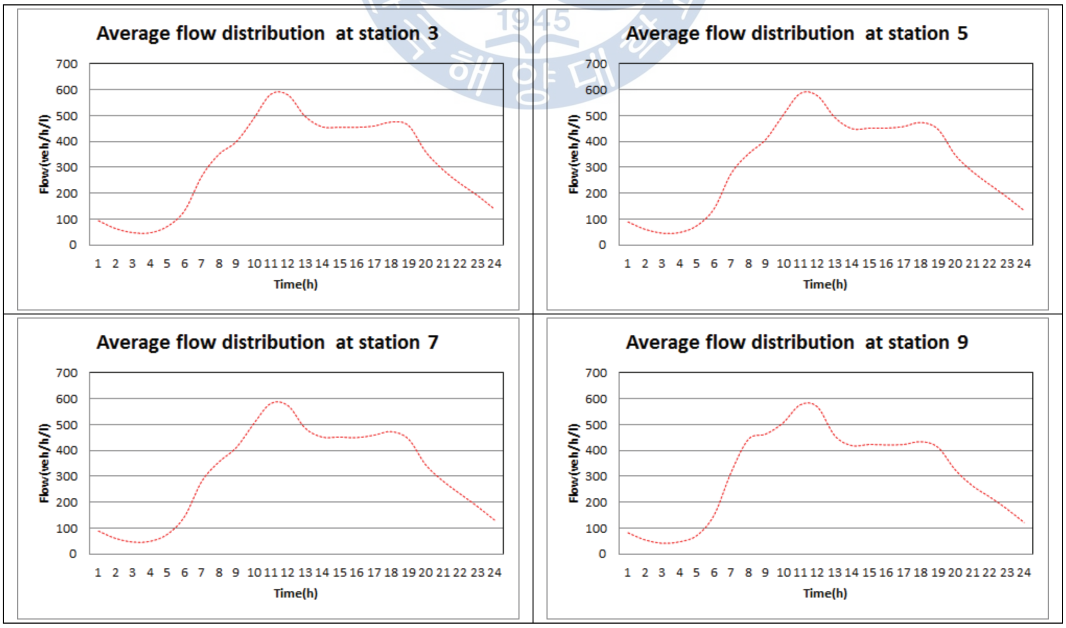


Figure 3.7 Average flow distribution of expressway Ex-10(WB)

Table 3.3 Flow analysis of expressway Ex-10(veh/h/l, %)

Direction /Station		Station 3		Station 5		Station 7		Station 9	
		Flow	Shift	Flow	Shift	Flow	Shift	Flow	Shift
EB	Max	594	+89	593	+90	596	+90	629	+101
	Min	41	-87	42	-87	42	-87	40	-87
	Avg	315	-	312	-	314	-	313	-
	AM-Peak	-	-	-	-	-	-	-	-
	PM-Peak	594	+89	593	+90	596	+90	629	+101
WB	Max	582	+84	586	+86	582	+84	576	+86
	Min	48	-85	46	-85	46	-85	42	-86
	Avg	317	-	316	-	315	-	309	-
	AM-Peak	582	+84	586	+86	582	+84	576	+86
	PM-Peak	-	-	-	-	-	-	-	-

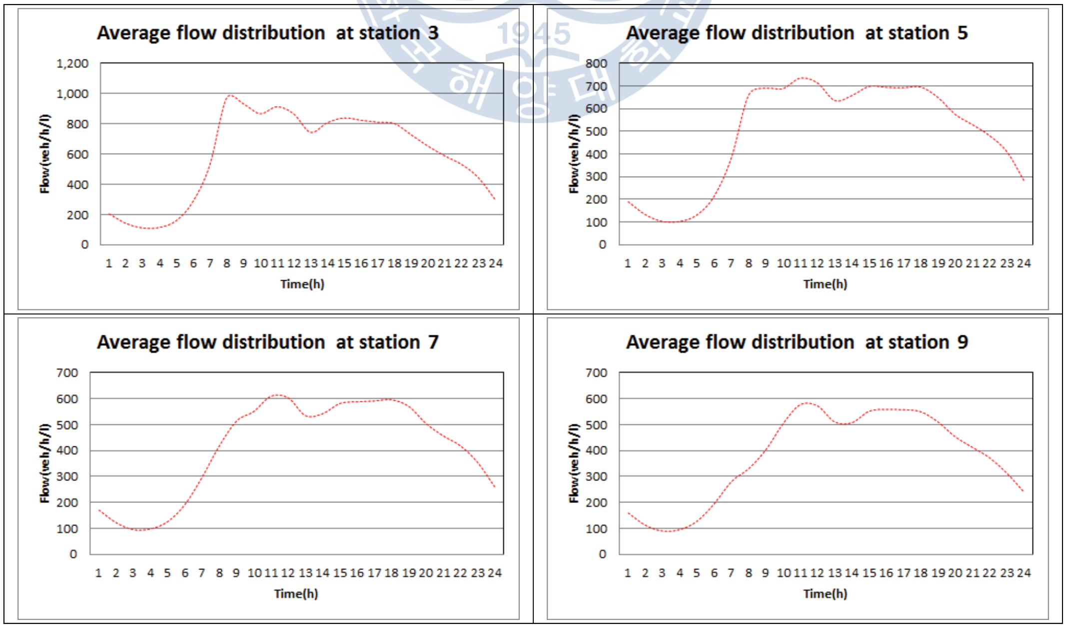


Figure 3.8 Average flow distribution of expressway Ex-1(NB)

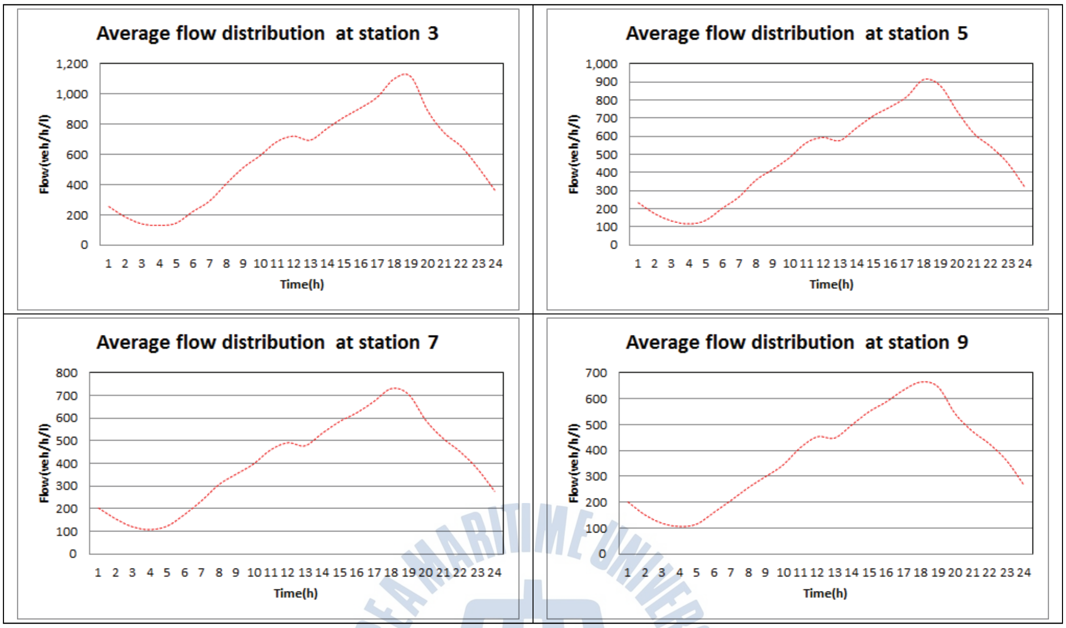


Figure 3.9 Average flow distribution of expressway Ex-1(SB)

Table 3.4 Flow analysis of expressway Ex-1(veh/h/l, %)

Direction /Station		Station 3		Station 5		Station 7		Station 9	
		Flow	Shift	Flow	Shift	Flow	Shift	Flow	Shift
NB	Max	971	+64	736	+50	610	+49	577	+54
	Min	111	-81	103	-79	96	-77	90	-76
	Avg	591	-	490	-	408	-	374	-
	AM-Peak	971	+64	736	+50	610	+49	577	+54
	PM-Peak	-	-	-	-	-	-	-	-
SB	Max	1,115	+93	913	+88	730	+81	665	+79
	Min	131	-77	117	-76	108	-73	107	-71
	Avg	578	-	486	-	403	-	375	-
	AM-Peak	-	-	-	-	-	-	-	-
	PM-Peak	1,115	+93	913	+88	730	+81	665	+79

3.2.1 Speed

Speed, as the distance traveled by the vehicle for a unit period, was converted into the station mean speed as follows(May, 1990);

$$u_s = \frac{3.6 \times d}{\bar{t}} = \frac{3.6 \times d}{\frac{1}{N}\sum_{i=1}^{N}(\frac{d}{u_i})} \qquad (3)$$

Where, u_s : mean speed at station(km/h)

d : distance between loop detectors at station(m)

$\bar{t}$: mean travel time(sec)

u_i : travel speed of each vehicle i(km/h)

N : no. of vehicles observed for 15 min(veh)

Speed distribution appeared to be hardly a big difference between the stations in the same direction for 2 weeks, but to be a clear difference between the directions in expressway for 2 weeks as shown in **Figures 3.10~3.13**.

On the one hand, speed analyses appeared to have no big difference with the different peak-period characteristics for each direction in Namhae expressway as summarized in **Table 3.5** and as shown in **Figures 3.14~3.15**. In the EB direction of Namhae expressway, the average speed appeared to be about 103km/h. And the minimum speed appeared to be about 94km/h showing a decrease of about 9% when compared with the average speed in the same direction, but the maximum speed appeared to be about 109km/h showing a increase of about 6% when compared with the average speed in the same direction. Also the peak-period speed appeared to be a slight difference with the maximum speed in the EB direction for the afternoon peak-period. In the WB direction of Namhae expressway, the average speed also appeared to be about 105km/h in the same direction. And the minimum speed appeared to be about 93km/h showing a decrease of about 11% when compared with the average speed in the same direction, but the maximum speed appeared to be about 110km/h showing a increase of about 6% when compared with the average speed in the same direction. Also the peak-period speed appeared to be a slight difference with the maximum speed in the WB direction for the morning peak-period unlike the EB direction.

On the other hand, speed analyses appeared to have no big difference with the different peak-period characteristics for each direction in Gyeongbu expressway as summarized in **Table 3.6** and as shown in **Figures 3.16~3.17**. In the NB direction of Gyeongbu expressway, the average speed appeared to be about 100km/h. And the minimum speed appeared to be about 91m/h showing a decrease of about 9% when compared with the average speed in the same direction, but the maximum speed appeared to be about 106km/h showing a increase of about 6% when compared with the average speed in the same direction. Also the peak-period speed appeared to be a slight difference with the maximum speed in the NB direction for the morning peak-period. In the SB direction of Gyeongbu expressway, the average speed also appeared to be about 101km/h. And the minimum speed appeared to be about 91km/h showing a decrease of about 10% when compared with the average speed in the same direction, but the maximum speed appeared to be about 107km/h showing a increase of about 6% when compared with the average speed in the same direction. Also the peak-period speed appeared to be a slight difference with the maximum speed in the SB direction of the afternoon peak-period unlike the NB direction.

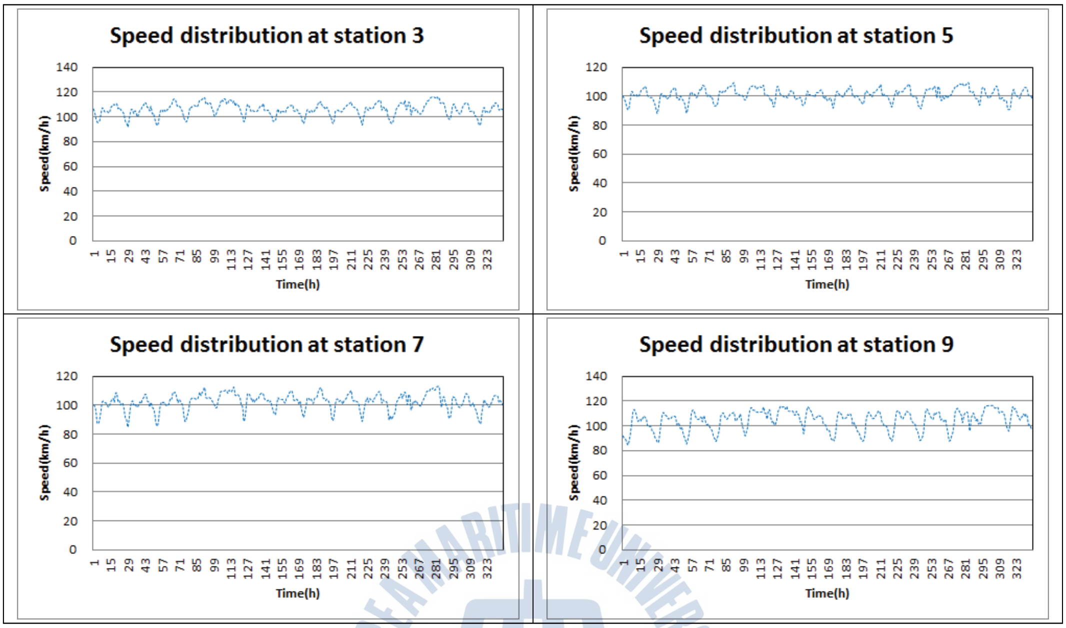


Figure 3.10 Speed distribution of expressway Ex-10(EB)

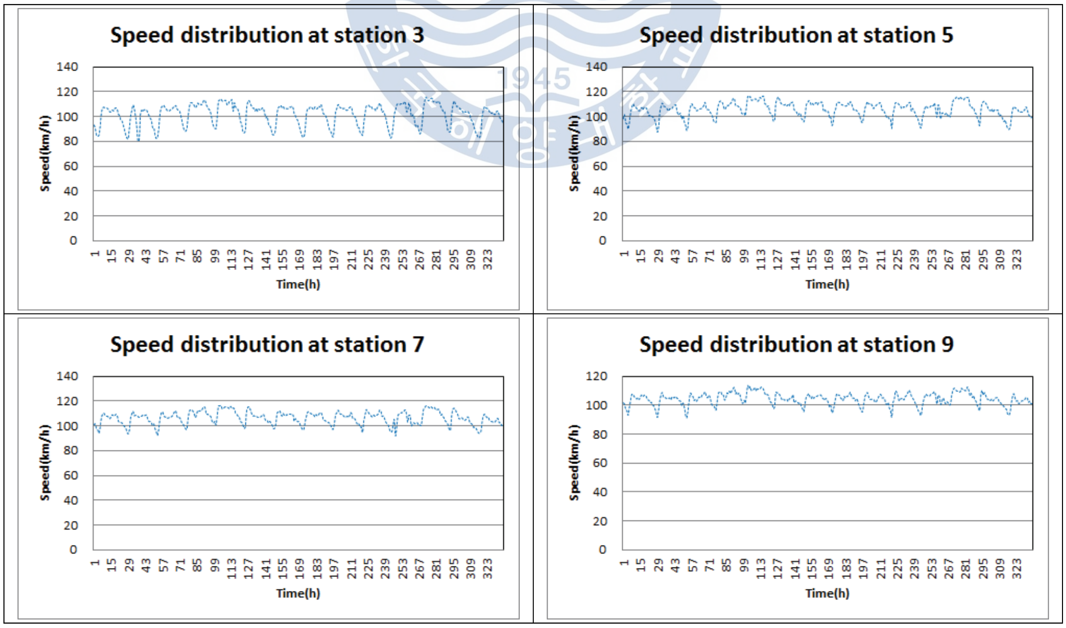


Figure 3.11 Speed distribution of expressway Ex-10(WB)

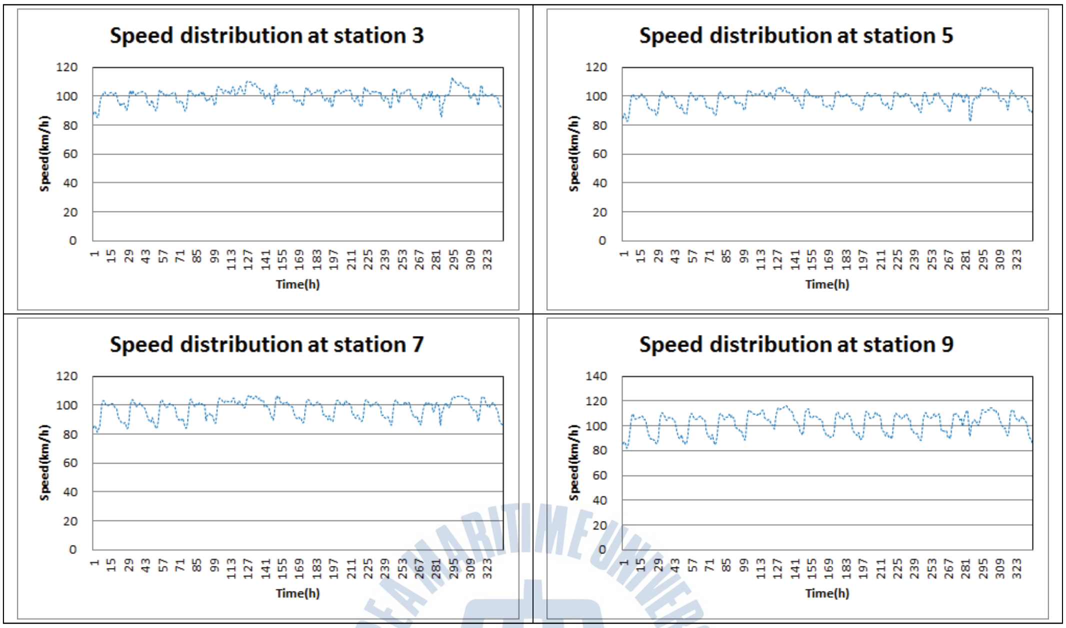


Figure 3.12 Speed distribution of expressway Ex-1(NB)

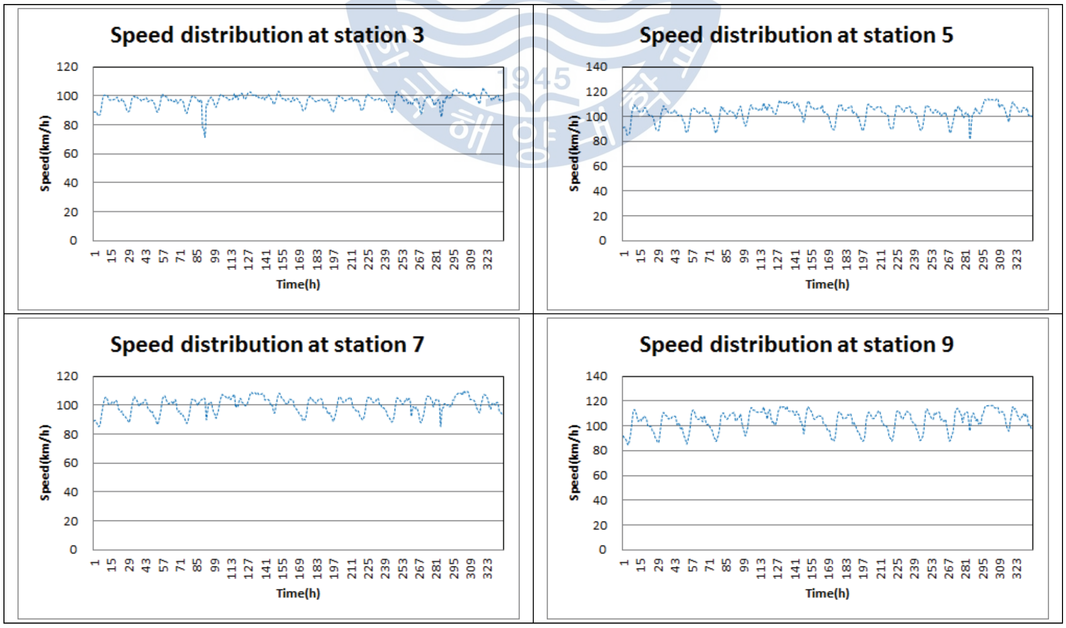


Figure 3.13 Speed distribution of expressway Ex-1(SB)

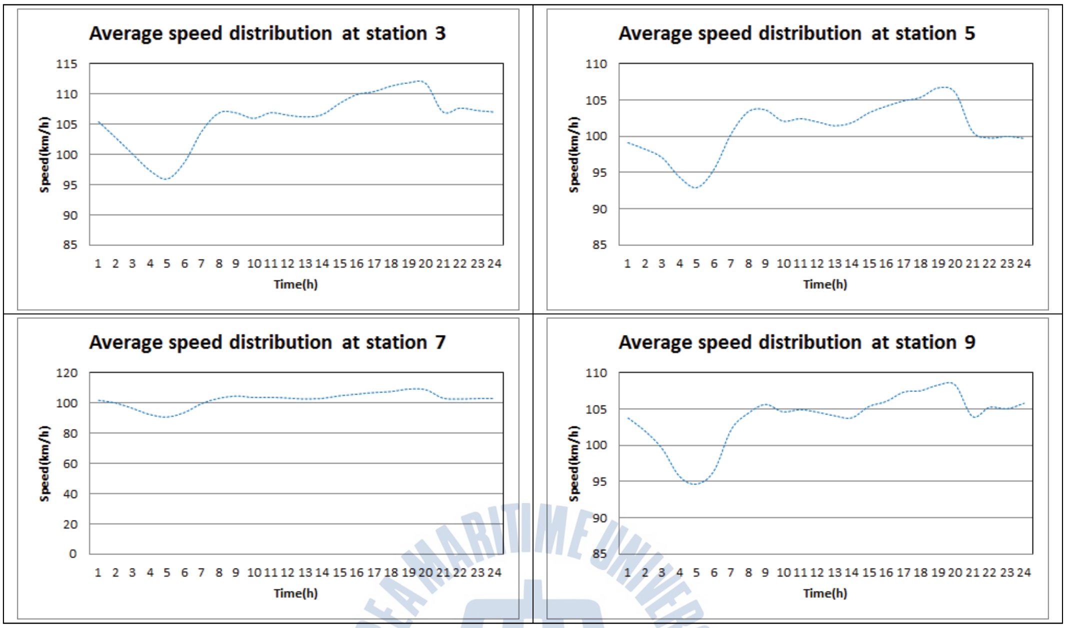


Figure 3.14 Average speed distribution of expressway Ex-10(EB)

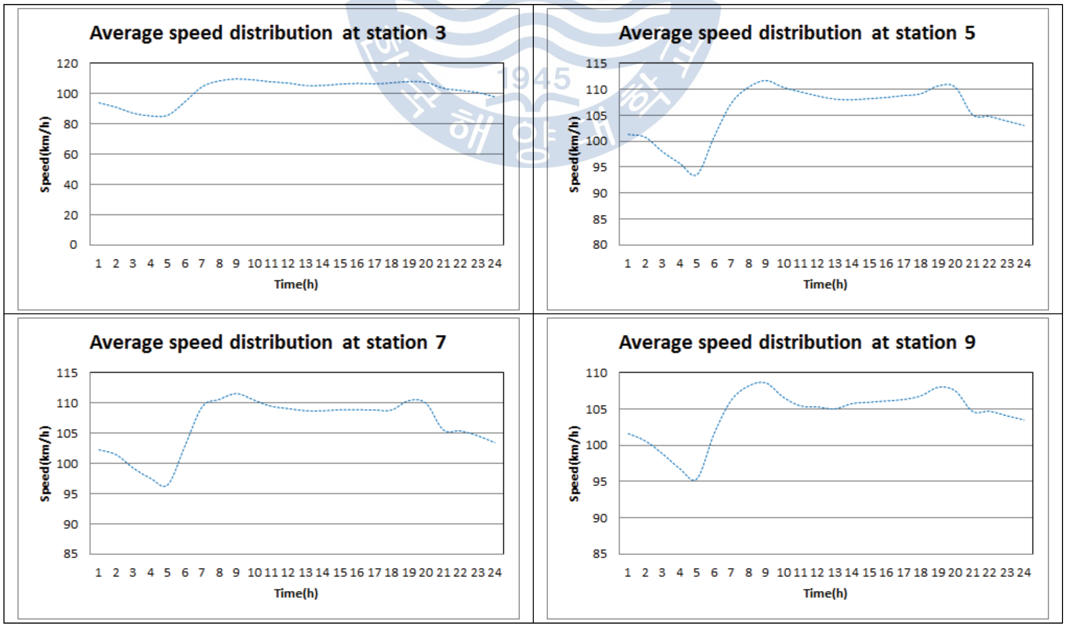


Figure 3.15 Average speed distribution of expressway Ex-10(WB)

Table 3.5 Speed analysis of expressway Ex-10(km/h, %)

Direction /Station		Station 3		Station 5		Station 7		Station 9	
		Speed	Shift	Speed	Shift	Speed	Shift	Speed	Shift
EB	Max	112	+6	107	+6	109	+7	108	+4
	Min	96	-9	93	-8	91	-11	95	-9
	Avg	106	-	101	-	102	-	104	-
	AM-Peak	-	-	-	-	-	-	-	-
	PM-Peak	100	-5	105	+4	107	+5	108	+4
WB	Max	110	+8	112	+6	112	+5	109	+4
	Min	85	-16	94	-11	96	-9	95	-9
	Avg	102	-	106	-	106	-	104	-
	AM-Peak	108	+6	110	+4	109	+3	105	+1
	PM-Peak	-	-	-	-	-	-	-	-

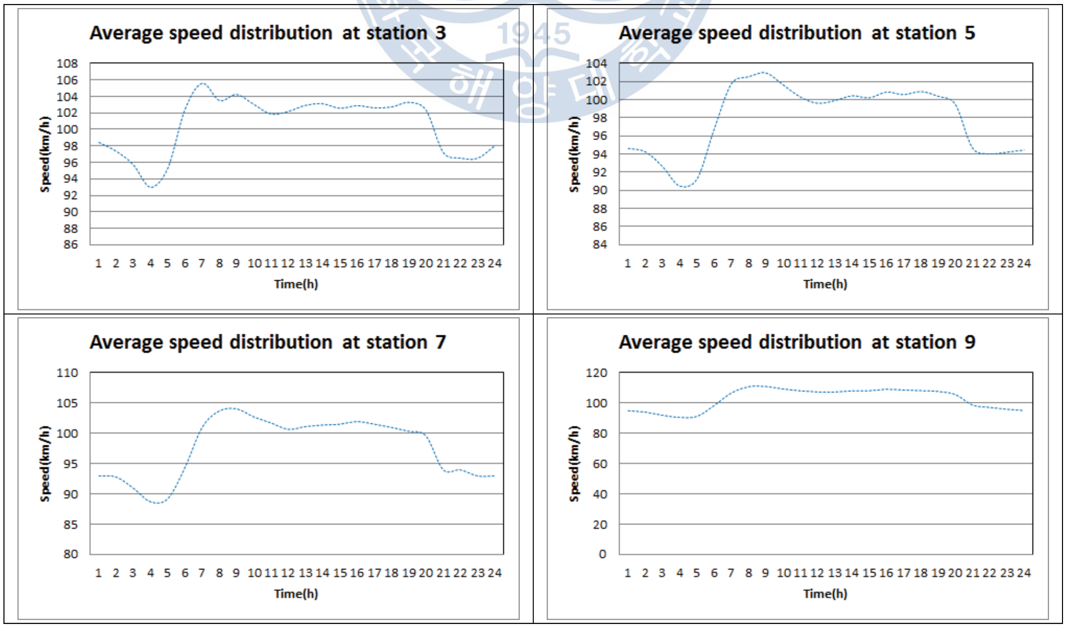


Figure 3.16 Average speed distribution of expressway Ex-1(NB)

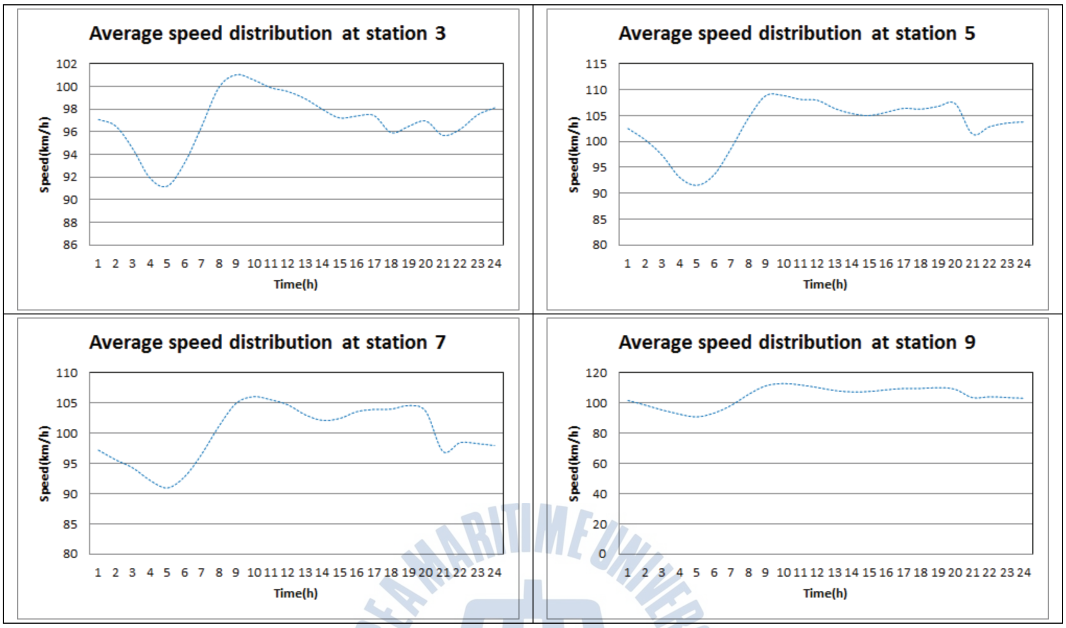


Figure 3.17 Average speed distribution of expressway Ex-1(SB)

Table 3.6 Speed analysis of expressway Ex-1(km/h, %)

Direction /Station		Station 3		Station 5		Station 7		Station 9	
		Speed	Shift	Speed	Shift	Speed	Shift	Speed	Shift
NB	Max	106	+5	103	+5	104	+6	111	+8
	Min	93	-8	90	-8	89	-9	91	-12
	Avg	101	-	98	-	98	-	103	-
	AM-Peak	103	+3	100	-2	102	+4	108	+5
	PM-Peak	-	-	-	-	-		-	-
SB	Max	101	+4	109	+6	106	+6	113	+8
	Min	91	-6	92	-11	91	-9	91	-13
	Avg	97	-	103	-	100	-	105	-
	AM-Peak	-	-	-	-	-	-	-	-
	PM-Peak	96	-1	106	+3	104	+4	110	+5

2.3 Occupancy

Occupancy, as a surrogate for density, was obtained by the percent(%) of the time that a loop detector was occupied as follows(May, 1990);

$$O = \frac{\sum_{i=1}^{N} (t_o)i}{t} \tag{4}$$

Where, O : occupancy(%)

$(t_o)_i$: time that detector is occupied by $i-th$ vehicle(sec)

N : number of vehicles detected for a unit time period t(veh)

t : a unit time period(15min)

Occupancy distribution appeared to be hardly a big difference between the stations in the same direction for 2 weeks, but to be a clear difference between the directions in expressway for 2 weeks as shown in **Figures 3.18~3.21**.

On the one hand, occupancy analyses appeared to have no big difference with the different peak-period characteristics for each direction in Namhae expressway as summarized in **Table 3.7** and as shown in **Figures 3.22~3.23**. In the EB direction of Namhae expressway, the average occupancy appeared to be about 2.8 percent(%). And the minimum occupancy appeared to be about 0.6 percent(%) showing a decrease of about 79% when compared with the average occupancy in the same direction, but the maximum occupancy appeared to be about 4.8 percent(%) showing a increase of about 69% when compared with the average occupancy in the same direction. Also the peak-period occupancy appeared to be a slight difference with the maximum occupancy in the EB direction for the afternoon peak-period. In the WB direction of Namhae expressway, the average occupancy also appeared to be about 2.8 percent(%) in the same direction. And the minimum occupancy appeared to be about 0.7 percent(%) showing a decrease of about 76% when compared with the average occupancy in the same direction, but the maximum occupancy appeared to be about 4.9 percent(%) showing a increase of about 74% when compared with the average occupancy in the same direction. Also the peak-period occupancy appeared to be almost consistent with the maximum occupancy in the WB direction for the morning peak-period unlike the EB direction.

On the other hand, occupancy analyses appeared to have a considerable difference with the different peak-period characteristics for each direction in Gyeongbu expressway as summarized in **Table 3.8** and as shown in **Figures 3.24~3.25**. In the NB direction of Gyeongbu expressway, the average occupancy appeared to be about 3.3 percent(%). And the minimum occupancy appeared to be about 1.2 percent(%) showing a decrease of about 64% when compared with the average occupancy in the same direction, but the maximum occupancy appeared to be about 4.8 percent(%) showing a increase of about 44% when compared with the average occupancy in the same direction. Also the peak-period occupancy appeared to be almost consistent with the maximum occupancy in the NB direction for the morning peak-period. In the SB direction of Gyeongbu expressway, the average occupancy also appeared to be about 3.1 percent(%). And the minimum occupancy appeared to be about 1.3 percent(%) showing a decrease of about 58% when compared with the average occupancy in the same direction, but the maximum occupancy appeared to be about 5.5 percent(%) showing a increase of about 75% when compared with the average occupancy in the same direction. Also the peak-period occupancy appeared to be a slight difference with the maximum occupancy in the SB direction of the afternoon peak-period unlike the NB direction.

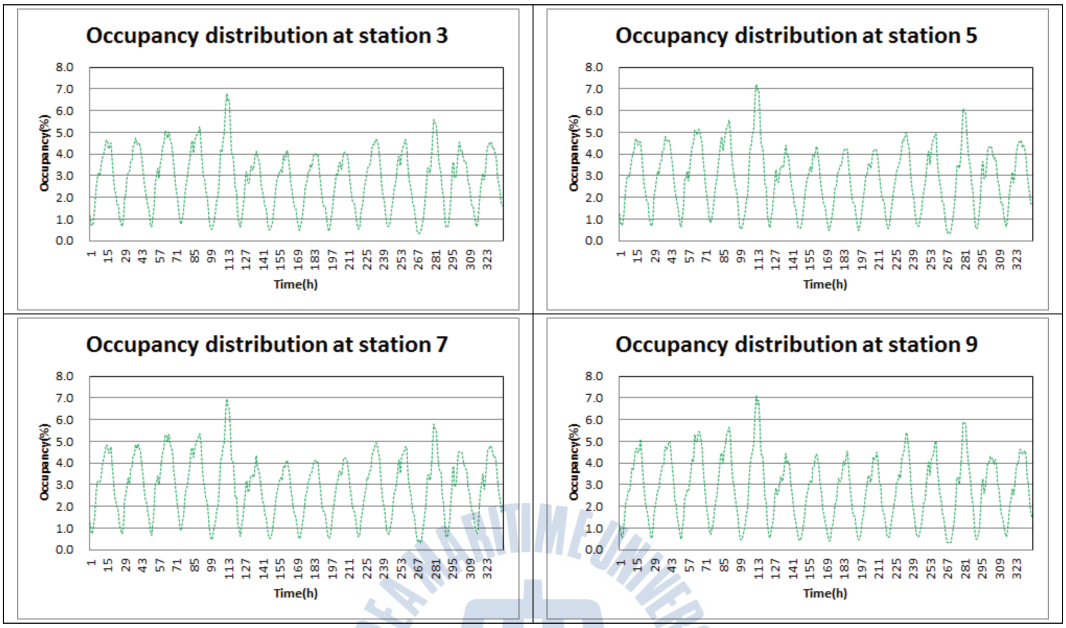


Figure 3.18 Occupancy distribution of expressway Ex-10(EB)

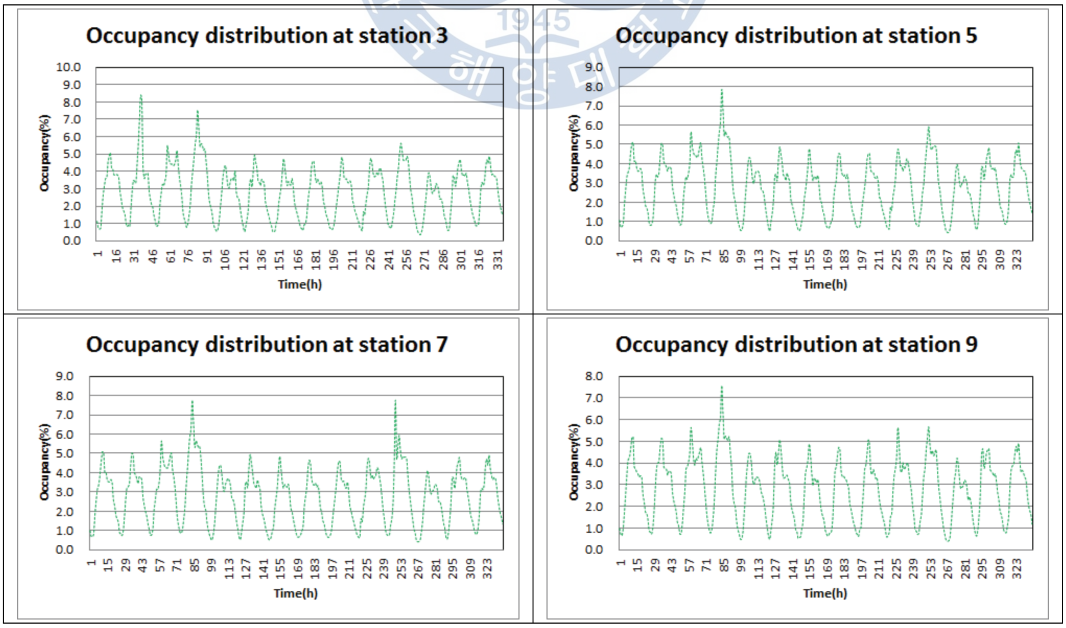


Figure 3.19 Occupancy distribution of expressway Ex-10(WB)

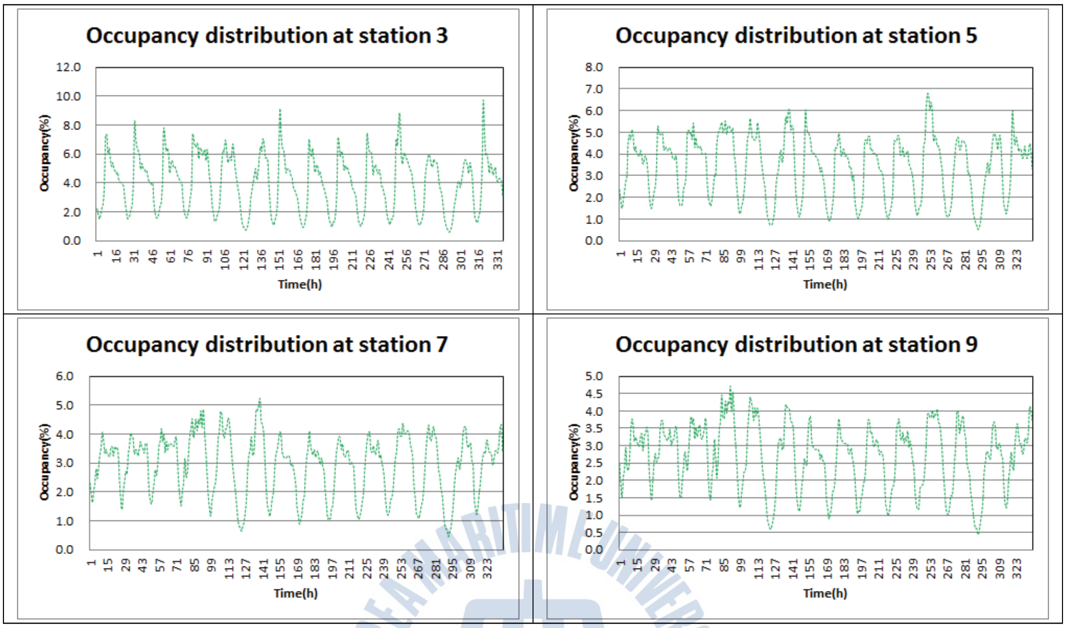


Figure 3.20 Occupancy distribution of expressway Ex-1(NB)

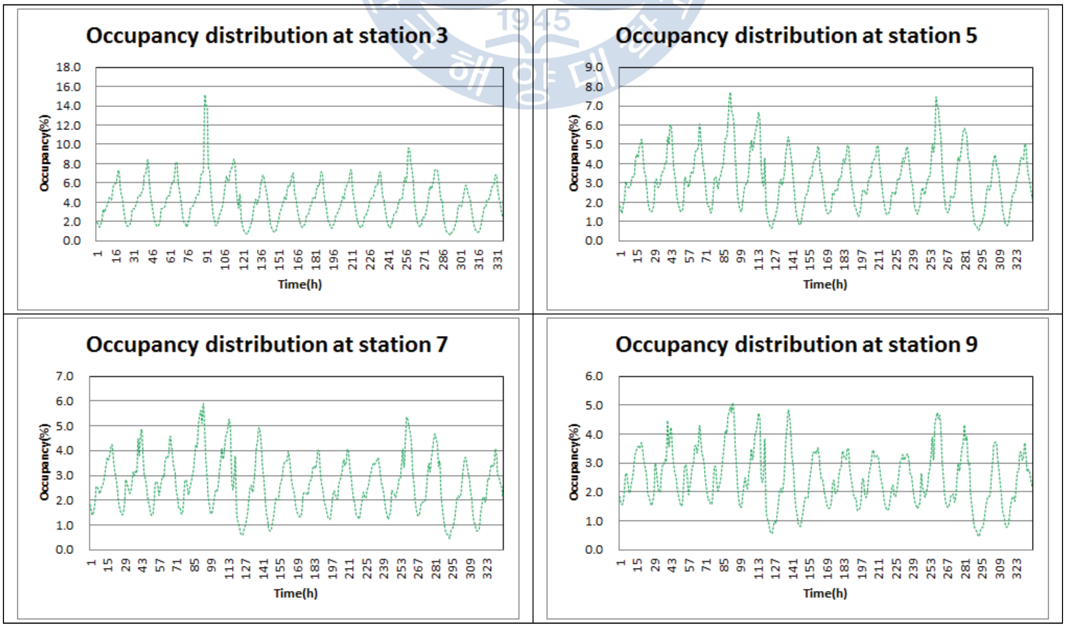


Figure 3.21 Occupancy distribution of expressway Ex-1(SB)

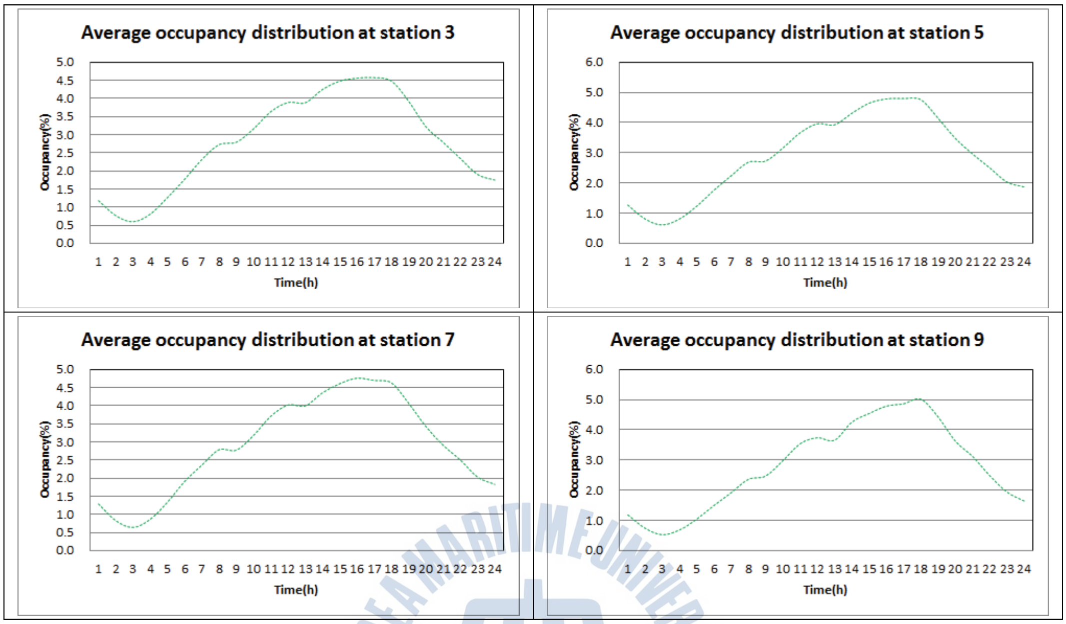


Figure 3.22 Average occupancy distribution of expressway Ex-10(EB)

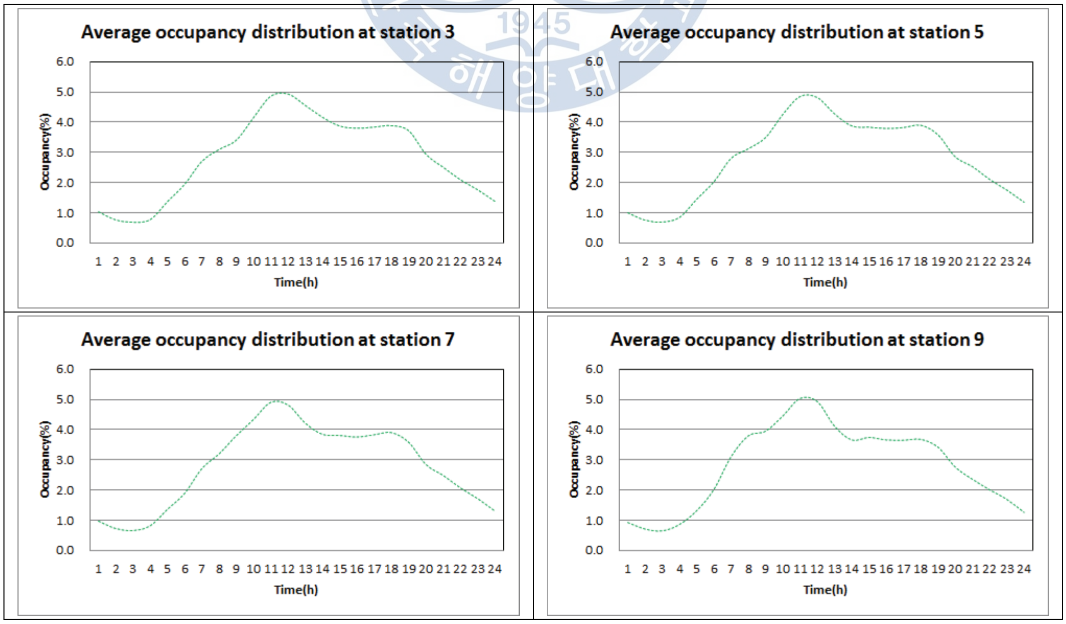


Figure 3.23 Average occupancy distribution of expressway Ex-10(WB)

Table 3.7 Occupancy analysis of expressway Ex-10(%)

Direction /Station		Station 3		Station 5		Station 7		Station 9	
		occupancy	Shift	occupancy	Shift	occupancy	Shift	occupancy	Shift
EB	Max	4.6	+64	4.8	+67	4.8	+64	5.0	+80
	Min	0.6	-79	0.6	+79	0.6	-78	0.5	-81
	Avg	2.8	-	2.9	-	2.9	-	2.8	-
	AM-Peak	-	-	-	-	-	-	-	-
	PM-Peak	3.7	+33	4.8	+67	4.7	+62	5.0	+80
WB	Max	4.9	+73	4.9	+72	4.9	+74	5.0	+78
	Min	0.7	-76	0.7	-75	0.7	-76	0.6	-77
	Avg	2.8	-	2.8	-	2.8	-	2.8	-
	AM-Peak	4.9	+71	4.9	+72	4.9	+74	5.0	+78
	PM-Peak	-		-	-	-	-	-	

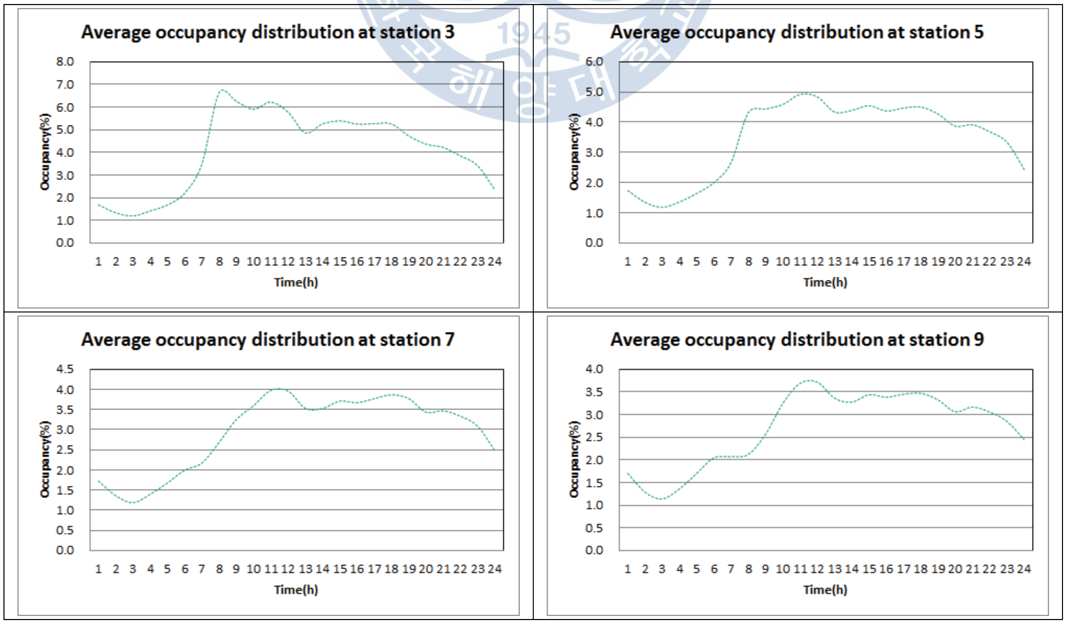


Figure 3.24 Average occupancy distribution of expressway Ex-1(NB)

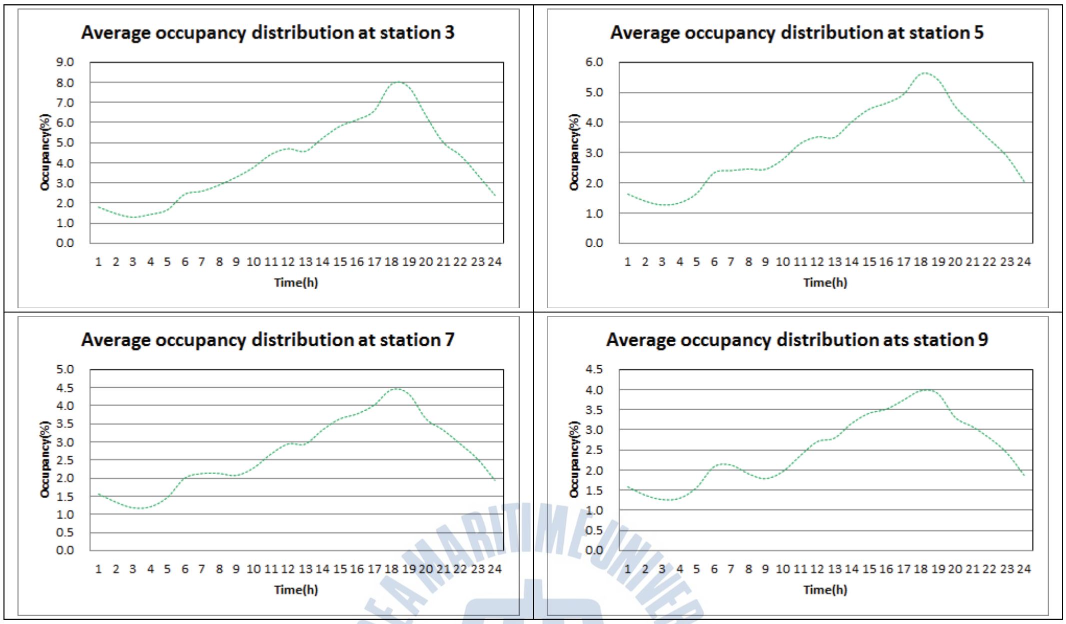


Figure 3.25 Average occupancy distribution of expressway Ex-1(SB)

Table 3.8 Occupancy analysis of expressway Ex-10(%)

Direction /Station		Station 3		Station 5		Station 7		Station 9	
		occupancy	Shift	occupancy	Shift	occupancy	Shift	occupancy	Shift
NB	Max	6.6	+63	4.9	+42	4.0	+35	3.7	+37
	Min	1.2	-71	1.2	-66	1.2	-60	1.1	-58
	Avg	4.1	-	3.5	-	2.9	-	2.7	-
	AM-Peak	6.6	+63	4.9	+42	4.0	+35	3.7	+37
	PM-Peak	-	-	-	-	-	-	-	-
SB	Max	7.9	+95	5.6	+77	4.4	+67	4.0	+59
	Min	1.3	-68	1.3	-60	1.2	-56	1.3	-49
	Avg	4.1	-	3.2	-	2.7	-	2.5	-
	AM-Peak	-	-	-	-	-	-	-	-
	PM-Peak	7.8	+92	5.6	+77	4.4	+67	4.0	+59

Traffic flow characteristics appeared to show a considerable difference in the direction of the basic expressway segments. So, the expressway traffic management systems such as advanced traveler management systems/advanced traveler information systems(ATMS/ATIS) and variable message signs(VMS) appeared to need to be deployed so that the real-time traffic information could be provided for the users based on the directional traffic flow characteristics in rural expressways.

4. Analysis of HV Factor(K) and Estimate K_j

4.1 Definition

The hourly volume(HV) factor is defined as the proportion of annual average daily traffic(AADT) occurring in an hour of the year by a decimal fraction as follows;

$$K = \frac{Q}{AADT} \tag{4.1}$$

where, K : hourly volume factor

Q : hourly volume(veh/h)

$AADT$: annual average daily traffic(veh/day)

The estimate of hourly volume factor(K_j) can be also defined as the proportion of average daily traffic(ADT_j) occurring in an hour for a short-term period by a decimal fraction as follows;

$$K_j = \frac{Q}{ADT_j} \tag{4.2}$$

where, K_j : estimate j of hourly volume factor(j=1, 3, 5, and 7)

Q : hourly volume(veh/h)

ADT_j : average daily traffic for a short-term period j(j=1, 3, 5, and 7 days)(veh/day)

The annual average daily traffic(AADT) in Namhae expressway appeared to have no big difference between the stations, but the annual average daily traffic(AADT) in Gyeongbu expressway appeared to have a big difference between the stations as presented in **Table 4.1** and shown in **Figure 4.1**. Also, the hourly volume factor(K) was determined by using AADT presented in **Table 4.1** and estimate K_j was determined by using ADT_j averaged for a short-term period; estimate K_1 by ADT_1 for a day from 00:00 till 24:00, estimate K_3 by ADT_3 for 3 days from Tuesday to Thursday, estimate K_5 by ADT_5 for 5 days from Monday to Friday, and estimate K_7 by ADT_7 for 7 days from Sunday to Saturday.

Table 4.1 AADT at stations of expressway(veh/day)

Station \ Expressway	Ex-10	Ex-1
Station 1	49,150	150,060
Station 2	54,211	150,060
Station 3	54,211	121,231
Station 4	56,223	121,231
Station 5	56,223	103,905
Station 6	56,223	103,905
Station 7	56,223	87,972
Station 8	65,482	87,972
Station 9	65,482	80,545
Station 10	65,482	80,545

Source: Korea Expressway Corporation

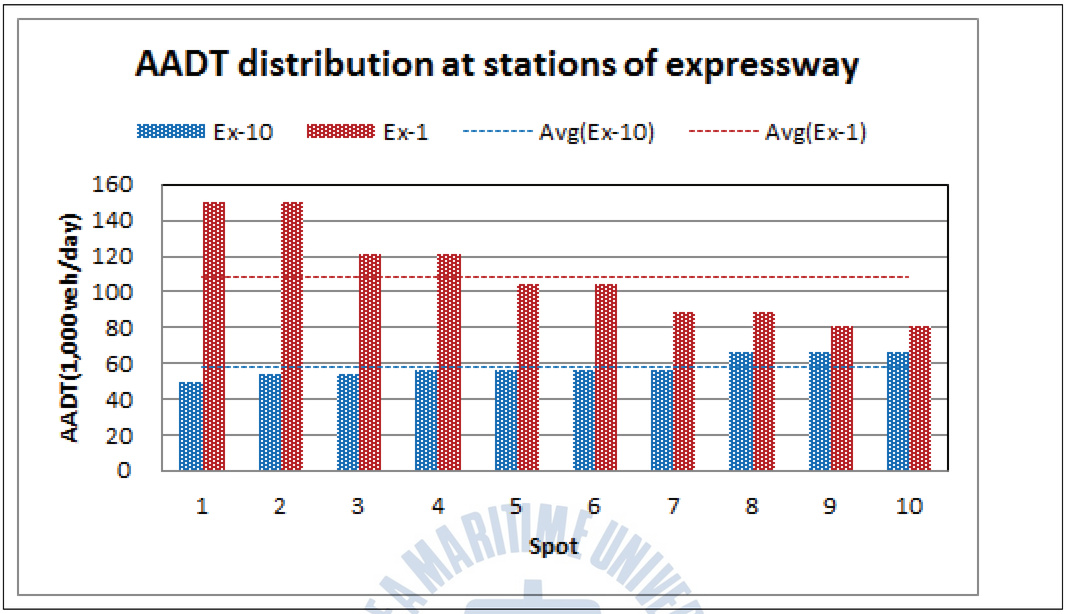


Figure 4.1 AADT distribution at stations of expressway

So, the analyses of K and estimate K_j seemed to be required to be conducted on the basis of the directional flow characteristics of expressways under the study.

4.2 Analysis of K and estimate K_j in expressway Ex-10

For the characteristic analyses of K and estimate K_j, the hourly proportions of K and estimate K_j were compared with each other unranked as well as ranked. As a rule, the highest hourly proportions of K appeared to show the rural traffic flow characteristics($K \geq 0.12$), but those proportions of estimate K_j appeared to show the rural and partially urban traffic flow characteristics depending on estimate K_j.

4.2.1 Unranked hourly proportions of K and estimate K_j

The hourly proportion distributions of K and estimate K_j appeared to show a clear difference at the stations in expressway Ex-10, but to hardly show a big difference in the directions of expressway Ex-10 when both K and estimate K_j were unranked as shown in **Figures 4.2~4.5**.

Particularly the hourly proportions of unranked K appeared to be in the range of 0.004 to 0.148 in EB and be similarly in the range of 0.004 to 0.143 in WB, but they appeared to be completely different between the directions for each station. However, the hourly proportions of unranked estimates K_1 and K_7 appeared to be equally in the range of 0.003 to 0.099 in EB and WB, and in the range of 0.004 to 0.131 in EB and 0.004 to 0.130 in WB showing the lower proportions than unranked K as presented in **Tables 4.2**, **4.3** and **4.6**. Whereas, the hourly proportions of unranked estimate K_3 appeared to be in the range of 0.004 to 0.151 in EB and in the range of 0.004 to 0.148 in WB showing the higher proportions than unranked K as presented in **Tables 4.2** and **4.4**. And those of unranked estimate K_5 appeared to be in the range of 0.004 to 0.146 in EB and 0.004 to 0.143 in WB showing almost the same proportions as unranked K as presented in **Tables 4.2** and **4.5**.

So, the hourly proportions of K and estimate K_j when both K and estimate K_j were unranked at the stations in expressway Ex-10 seemed to need to be ranked for determining the estimate K_j that could fit well with K.

Table 4.2 K analysis at stations of expressway Ex-10

Station \ Direction	EB			WB		
	Max	Min	Avg	Max	Min	Avg
Station 1	0.148	0.004	0.045	0.109	0.004	0.037
Station 2	0.129	0.005	0.045	0.143	0.004	0.045
Station 3	0.147	0.004	0.046	0.135	0.005	0.047
Station 4	0.142	0.004	0.045	0.132	0.005	0.045
Station 5	0.141	0.004	0.044	0.131	0.005	0.045
Station 6	0.131	0.005	0.044	0.143	0.004	0.044
Station 7	0.143	0.004	0.045	0.131	0.005	0.045
Station 8	0.141	0.004	0.044	0.126	0.005	0.044
Station 9	0.117	0.004	0.038	0.109	0.004	0.038
Station 10	0.129	0.004	0.045	0.144	0.004	0.045

Table 4.3 Estimate K_1 analysis at stations of expressway Ex-10

Station \ Direction	EB			WB		
	Max	Min	Avg	Max	Min	Avg
Station 1	0.099	0.003	0.042	0.089	0.005	0.042
Station 2	0.086	0.005	0.042	0.097	0.003	0.042
Station 3	0.097	0.003	0.042	0.087	0.005	0.042
Station 4	0.096	0.003	0.042	0.091	0.005	0.042
Station 5	0.098	0.003	0.042	0.091	0.005	0.042
Station 6	0.090	0.005	0.042	0.097	0.003	0.042
Station 7	0.097	0.003	0.042	0.090	0.005	0.042
Station 8	0.098	0.003	0.042	0.088	0.005	0.042
Station 9	0.095	0.004	0.042	0.089	0.005	0.042
Station 10	0.089	0.005	0.042	0.099	0.003	0.042

Table 4.4 Estimate K_3 analysis at stations of expressway Ex-10

Station \ Direction	EB			WB		
	Max	Min	Avg	Max	Min	Avg
Station 1	0.151	0.004	0.047	0.136	0.005	0.047
Station 2	0.132	0.005	0.046	0.147	0.004	0.046
Station 3	0.145	0.004	0.046	0.131	0.005	0.046
Station 4	0.146	0.004	0.046	0.133	0.005	0.046
Station 5	0.145	0.004	0.046	0.133	0.005	0.046
Station 6	0.134	0.005	0.046	0.148	0.004	0.046
Station 7	0.147	0.005	0.046	0.133	0.005	0.046
Station 8	0.149	0.004	0.046	0.131	0.005	0.046
Station 9	0.138	0.004	0.046	0.130	0.005	0.046
Station 10	0.128	0.005	0.046	0.145	0.004	0.046

Table 4.5 Estimate K_5 analysis at stations of expressway Ex-10

Station \ Direction	EB			WB		
	Max	Min	Avg	Max	Min	Avg
Station 1	0.146	0.004	0.045	0.128	0.004	0.044
Station 2	0.125	0.005	0.044	0.148	0.004	0.045
Station 3	0.140	0.004	0.045	0.125	0.005	0.044
Station 4	0.141	0.004	0.045	0.126	0.005	0.044
Station 5	0.141	0.004	0.045	0.126	0.005	0.044
Station 6	0.127	0.005	0.044	0.143	0.004	0.045
Station 7	0.142	0.004	0.045	0.126	0.005	0.044
Station 8	0.144	0.004	0.045	0.125	0.005	0.044
Station 9	0.134	0.004	0.044	0.123	0.005	0.044
Station 10	0.122	0.004	0.044	0.140	0.004	0.044

Table 4.6 Estimate K_7 analysis at stations of expressway Ex-10

Station \ Direction	EB			WB		
	Max	Min	Avg	Max	Min	Avg
Station 1	0.131	0.004	0.042	0.118	0.004	0.042
Station 2	0.116	0.005	0.042	0.129	0.004	0.042
Station 3	0.127	0.004	0.042	0.116	0.004	0.042
Station 4	0.128	0.004	0.042	0.117	0.004	0.042
Station 5	0.127	0.004	0.042	0.117	0.005	0.042
Station 6	0.118	0.005	0.042	0.130	0.004	0.042
Station 7	0.129	0.004	0.042	0.117	0.005	0.042
Station 8	0.130	0.004	0.042	0.116	0.005	0.042
Station 9	0.122	0.004	0.042	0.115	0.005	0.042
Station 10	0.114	0.004	0.042	0.128	0.003	0.042

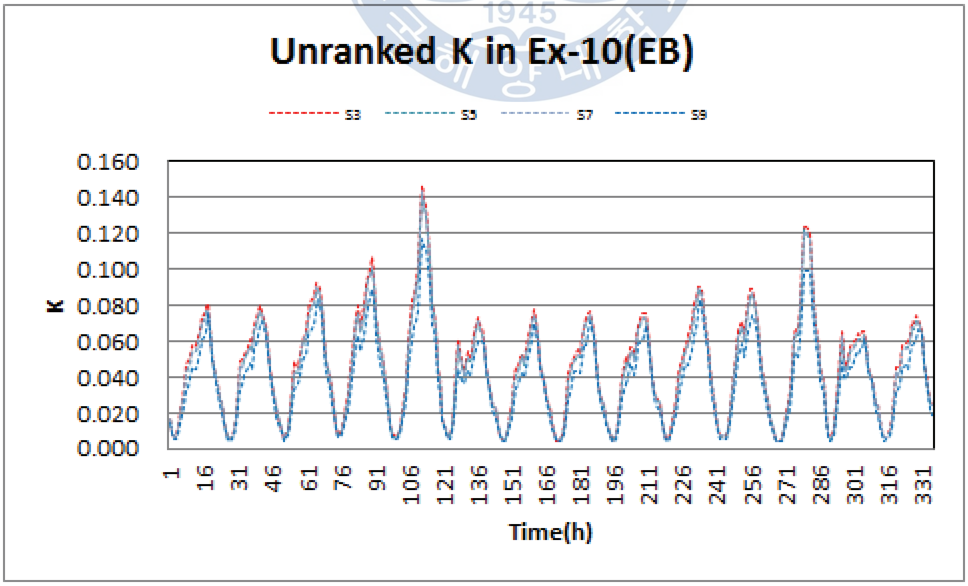


Figure 4.2 Unranked K in expressway Ex-10(EB)

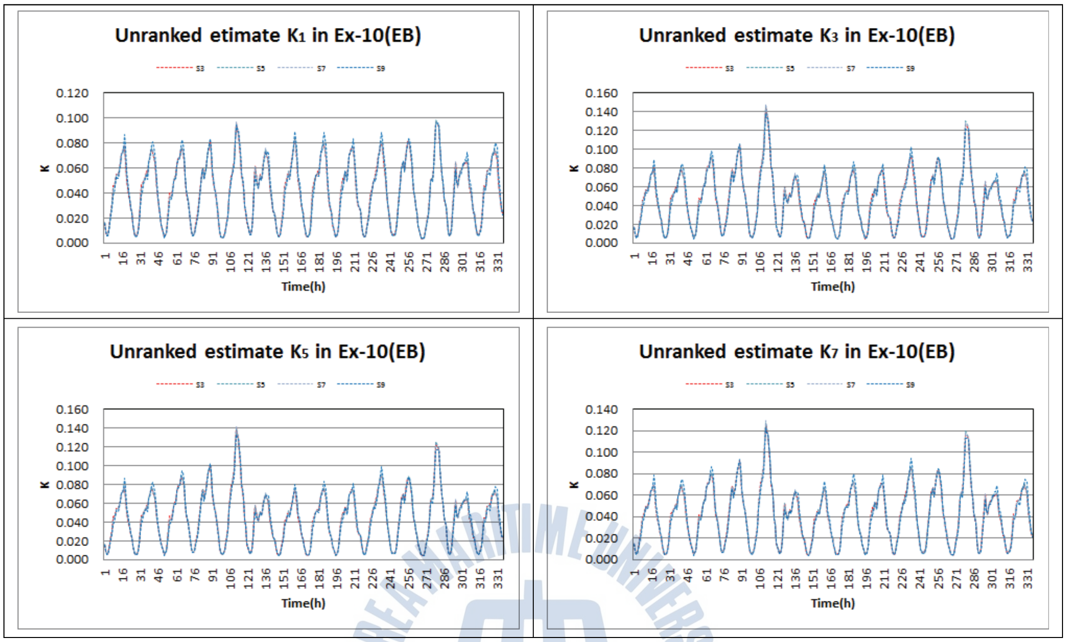


Figure 4.3 Unranked estimate K_j in expressway Ex-10(EB)

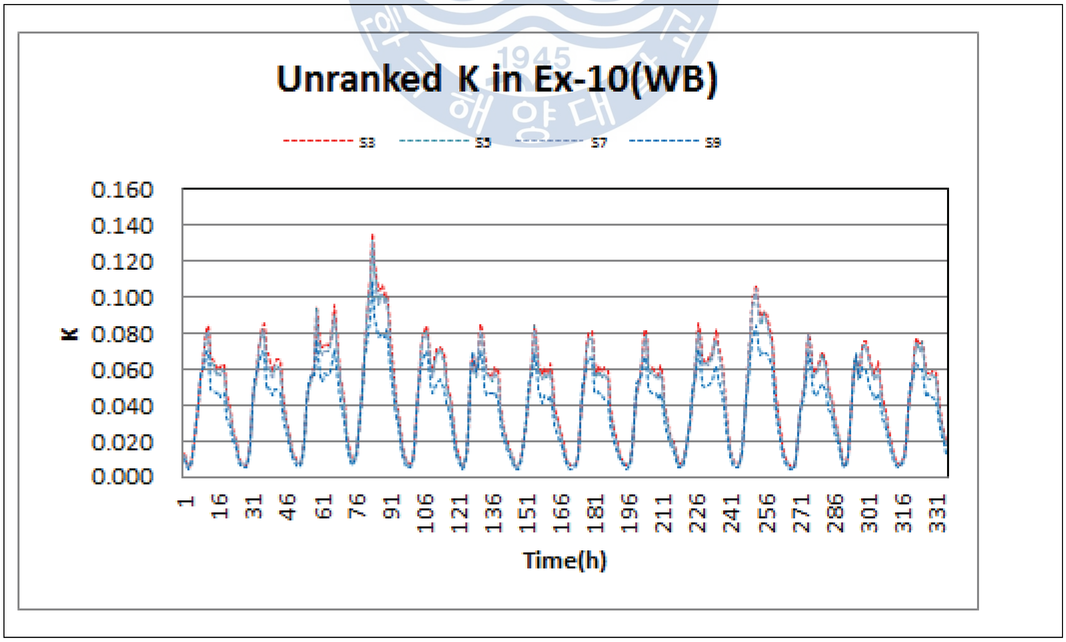


Figure 4.4 Unranked K in expressway Ex-10(WB)

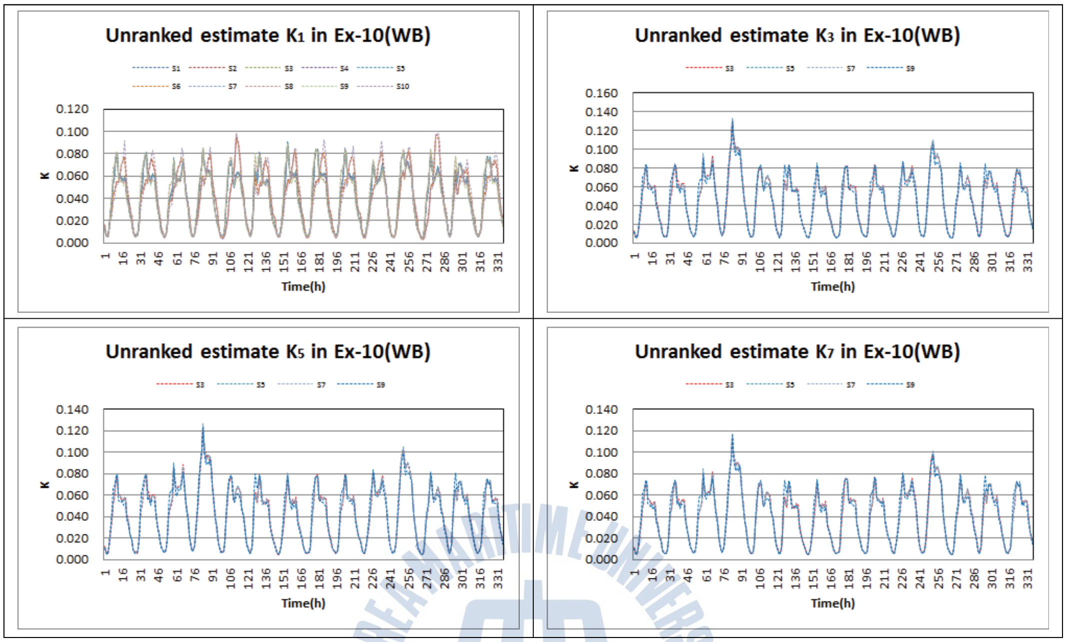


Figure 4.5 Unranked estimate K_j in expressway Ex-10(WB)

4.2.2 Ranked hourly proportion of K and estimate K_j

The hourly proportion distributions of K and estimate K_j appeared to show a considerable difference when K was only ranked at the stations in expressway Ex-10, but those distributions of K and estimate K_j appeared to show a clear difference when both K and etimate K_j were ranked at the stations in expressway Ex-10 as shown in **Figures 4.6~4.13**.

Particularly when compared with the hourly proportions between ranked K and unranked estimate K_j at the stations in expressway Ex-10, the hourly proportions of ranked K appeared to be in the upper part than those of unranked estimate K_j showing the similar distributions in the hourly proportions of unranked estimate K_j at the stations 3, 5, and 7 in EB and WB. But they appeared to be in the lower part rather than those of unranked estimate K_j showing the similar distributions in the hourly proportions of unranked estimate K_j at the station 9 in EB and WB as shown in **Figures 4.6~4.9**.

Also when compared with the hourly proportions between ranked K and ranked estimate K_j at the stations, the hourly proportions of ranked K appeared to be close with those of ranked estimates K_3 and K_5 showing the similar distributions in the hourly proportions of ranked estimate K_j in EB and WB. But they appeared to be close with those of ranked estimate K_7 showing the similar distributions in the hourly proportions of ranked estimate K_j at the station 9 in EB and WB as shown in **Figures 4.10~4.13**.

So, the correlative analysis between ranked K and ranked estimate K_j at the stations in expressway Ex-10 seemed to need to be performed for determining the estimate K_j that could fit well with K.

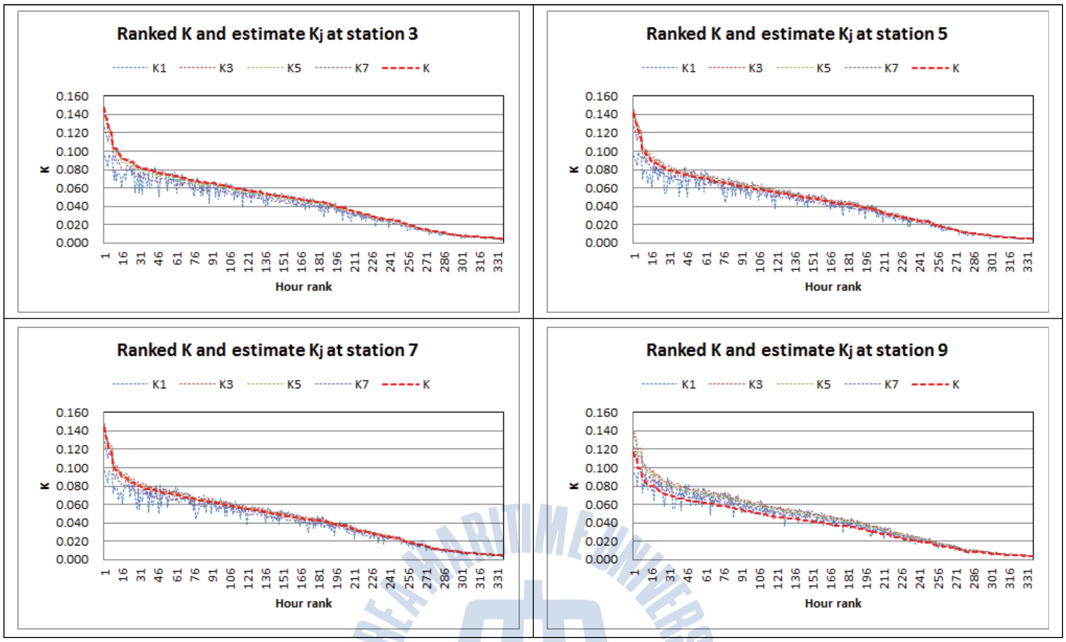


Figure 4.6 Ranked K and unranked estimate K_j in expressway Ex-10(EB)

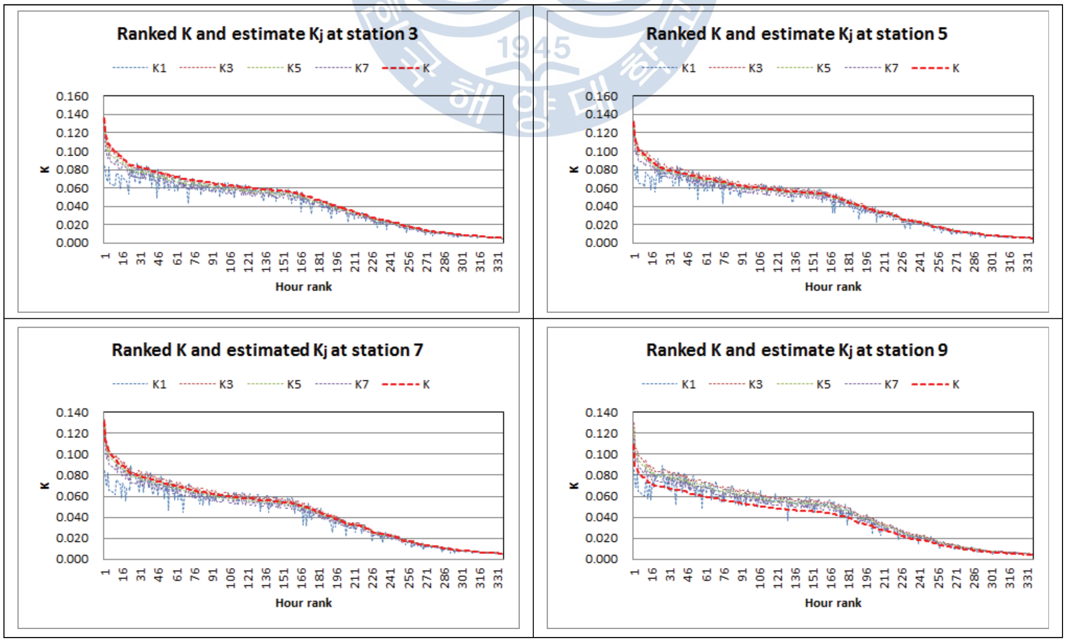


Figure 4.7 Ranked K and unranked estimate K_j in expressway Ex-10(WB)

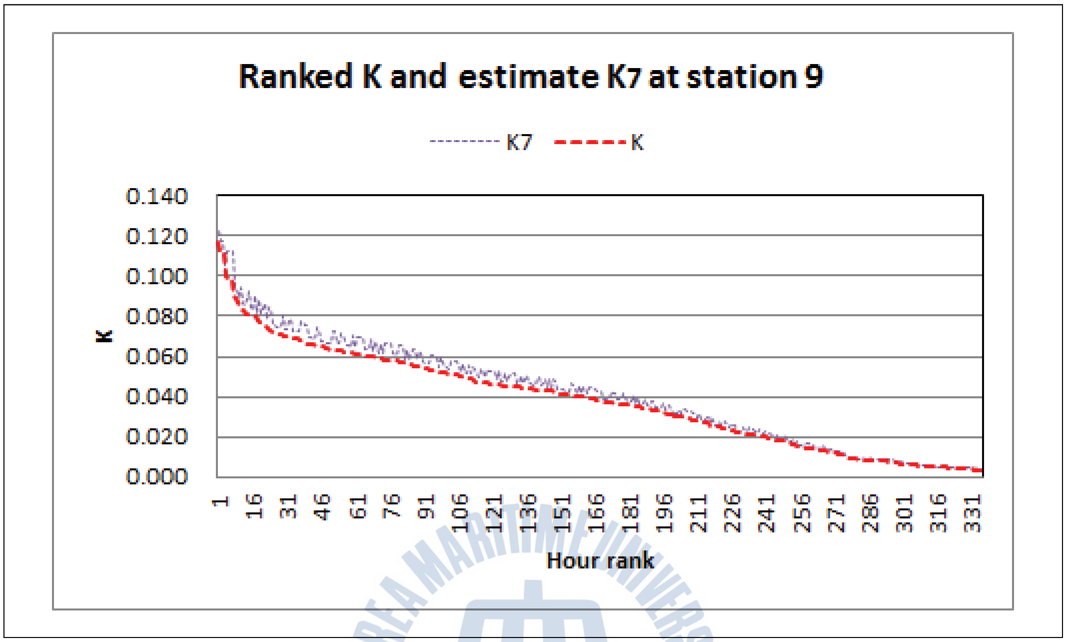


Figure 4.8 Ranked K and unranked estimate K_7 in expressway Ex-10(EB)

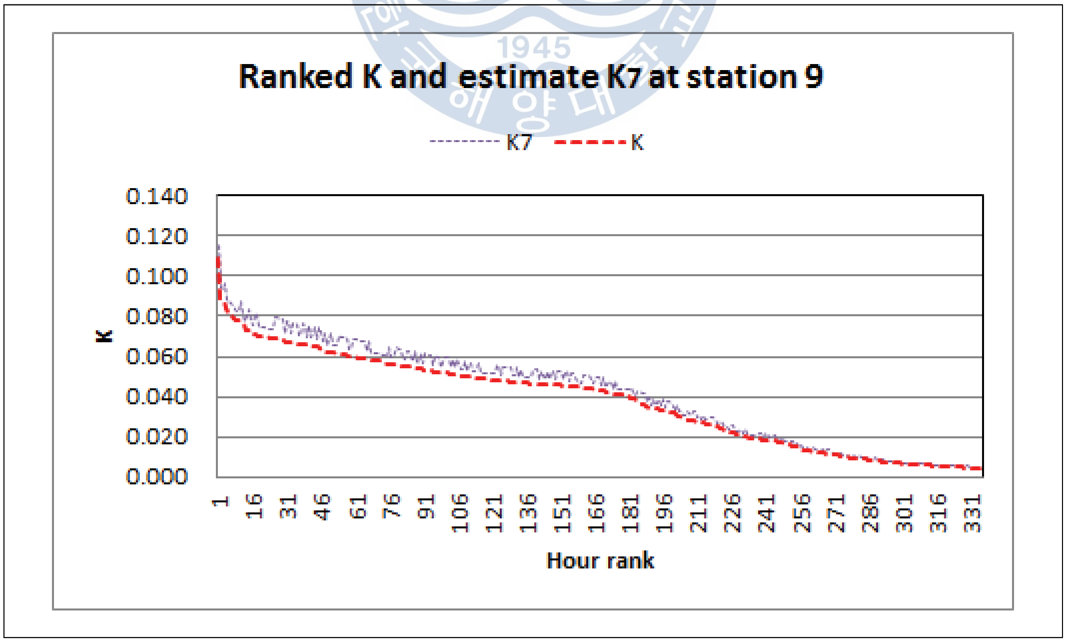


Figure 4.9 Ranked K and unranked estimate K_7 in expressway Ex-10(WB)

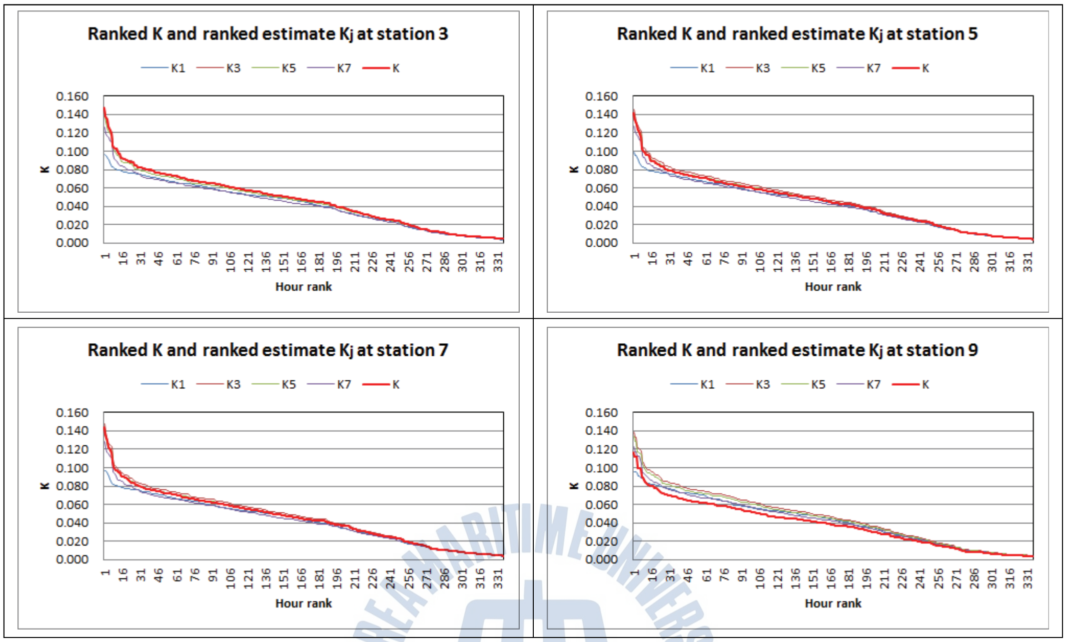


Figure 4.10 Ranked K and ranked estimate K_j in expressway Ex-10(EB)

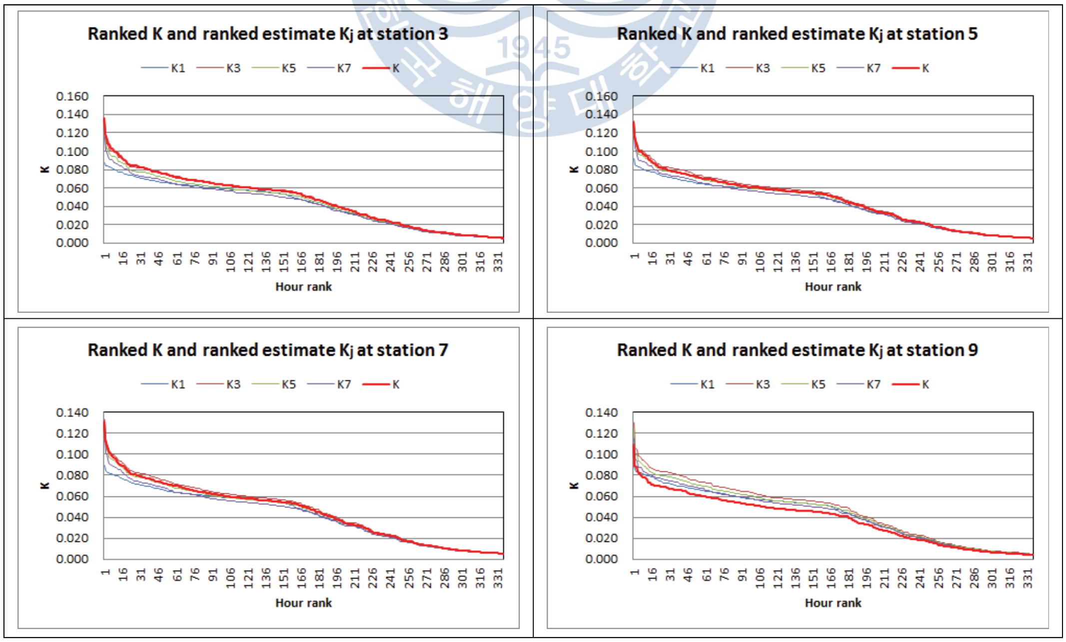


Figure 4.11 Ranked K and ranked estimate K_j in expressway Ex-10(WB)

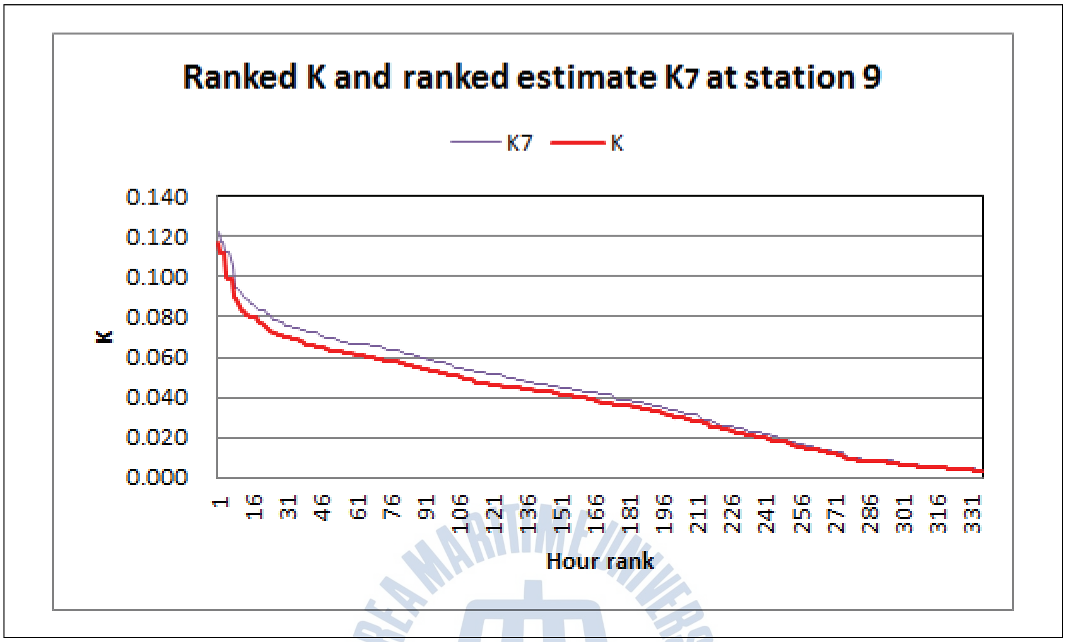


Figure 4.12 Ranked K and ranked estimate K_7 in expressway Ex-10(EB)

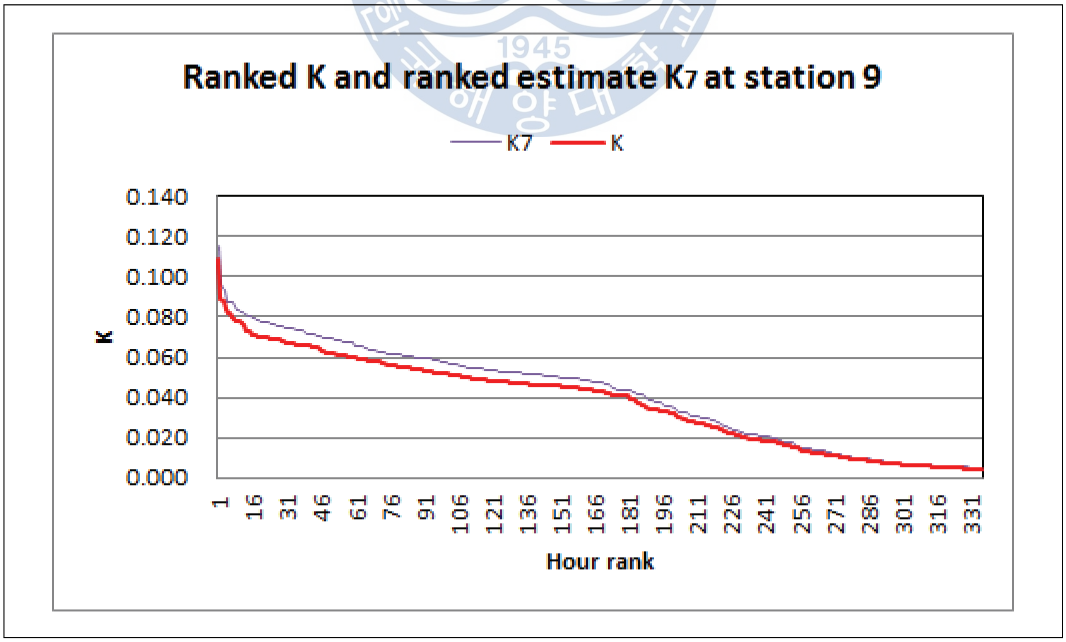


Figure 4.13 Ranked K and ranked estimate K_7 in expressway Ex-10(WB)

4.3 Analysis of K and estimate K_j in expressway Ex-1

For the characteristic analyses of K and estimate K_j, the hourly proportions of K and estimate K_j at the stations in expressway Ex-1 were compared with each other unranked as well as ranked. As a rule, the highest hourly proportions of K appeared to show the urban traffic flow characteristics($K < 0.12$), but those proportions of estimate K_j appeared to show the urban and partially rural traffic flow characteristics depending on estimate K_j.

4.3.1 Unranked hourly proportions of K and estimate K_j

The hourly proportion distributions of K and estimate K_j at the stations in expressway Ex-1 appeared to show a little difference between the stations, but to show a clear difference between the directions in expressway Ex-1 when both K and estimate K_j were unranked as shown in **Figures 4.14~4.17**.

Particularly the hourly proportions of unranked K appeared to be in the range of 0.004 to 0.089 in NB and be in the range of 0.003 to 0.102 in SB, but they appeared to be completely different between the directions for each station. Whereas the hourly proportions of unranked estimates K_1 and K_7 appeared to be in the range of 0.005 to 0.099 in NB, and in the range of 0.005 to 0.101 in NB and 0.005 to 0.118 in SB showing the higher proportions than unranked K as presented in **Table3 4.7**, **4.8** and **4.11**. And the hourly proportions of unranked estimate K_3 appeared to be in the range of 0.005 to 0.101 in NB and in the range of 0.005 to 0.112 in SB showing the higher proportions than unranked K as presented in **Tables 4.7** and **4.9**. Also those of unranked estimate K_5 appeared to be in the range of 0.005 to 0.097 in NB and 0.005 to 0.123 in SB showing the higher proportions than unranked K as presented in **Tables 4.14** and **4.10**.

So, the hourly proportions of K and estimate K_j when K and estimate K_j were unranked at the stations in expressway Ex-1 seemed to need to be ranked for determining the estimate K_j that could fit well with K.

Table 4.7 K analysis at stations of expressway Ex-1

Station \ Direction	NB			SB		
	Max	Min	Avg	Max	Min	Avg
Station 1	0.073	0.004	0.036	0.068	0.004	0.031
Station 2	0.077	0.004	0.037	0.094	0.004	0.040
Station 3	0.089	0.004	0.039	0.102	0.005	0.038
Station 4	0.088	0.005	0.039	0.094	0.005	0.038
Station 5	0.076	0.004	0.038	0.091	0.005	0.037
Station 6	0.076	0.005	0.038	0.081	0.003	0.032
Station 7	0.076	0.004	0.037	0.081	0.005	0.037
Station 8	0.076	0.005	0.037	0.084	0.005	0.037
Station 9	0.075	0.004	0.037	0.086	0.004	0.037
Station 10	0.075	0.004	0.037	0.086	0.005	0.038

Table 4.8 Estimate K_1 analysis at stations of expressway Ex-1

Station \ Direction	NB			SB		
	Max	Min	Avg	Max	Min	Avg
Station 1	0.086	0.005	0.042	0.078	0.006	0.042
Station 2	0.088	0.005	0.042	0.084	0.005	0.042
Station 3	0.095	0.005	0.042	0.093	0.006	0.042
Station 4	0.093	0.005	0.042	0.087	0.006	0.042
Station 5	0.080	0.005	0.042	0.086	0.006	0.042
Station 6	0.079	0.005	0.042	0.087	0.006	0.042
Station 7	0.076	0.005	0.042	0.087	0.006	0.042
Station 8	0.076	0.005	0.042	0.087	0.006	0.042
Station 9	0.076	0.005	0.042	0.094	0.006	0.042
Station 10	0.076	0.005	0.042	0.101	0.006	0.042

Table 4.9 Estimate K_3 analysis at stations of expressway Ex-1

Station \ Direction	NB			SB		
	Max	Min	Avg	Max	Min	Avg
Station 1	0.089	0.005	0.043	0.093	0.006	0.043
Station 2	0.090	0.005	0.043	0.099	0.005	0.043
Station 3	0.101	0.005	0.043	0.112	0.005	0.043
Station 4	0.100	0.005	0.043	0.104	0.005	0.043
Station 5	0.087	0.005	0.044	0.105	0.006	0.044
Station 6	0.087	0.006	0.044	0.108	0.005	0.043
Station 7	0.089	0.005	0.044	0.079	0.006	0.044
Station 8	0.089	0.006	0.044	0.079	0.006	0.044
Station 9	0.088	0.005	0.045	0.100	0.005	0.044
Station 10	0.087	0.005	0.045	0.091	0.005	0.042

Table 4.10 Estimate K_5 analysis at stations of expressway Ex-1

Station \ Direction	NB			SB		
	Max	Min	Avg	Max	Min	Avg
Station 1	0.086	0.005	0.042	0.090	0.005	0.042
Station 2	0.087	0.005	0.042	0.096	0.005	0.042
Station 3	0.097	0.005	0.042	0.109	0.005	0.042
Station 4	0.096	0.005	0.042	0.123	0.006	0.046
Station 5	0.084	0.005	0.042	0.102	0.005	0.042
Station 6	0.084	0.005	0.042	0.104	0.005	0.042
Station 7	0.086	0.005	0.043	0.094	0.006	0.042
Station 8	0.086	0.005	0.043	0.093	0.006	0.042
Station 9	0.085	0.005	0.043	0.096	0.005	0.042
Station 10	0.084	0.005	0.043	0.091	0.005	0.042

Table 4.11 Estimate K_7 analysis at stations of expressway Ex-1

Station \ Direction	NB			SB		
	Max	Min	Avg	Max	Min	Avg
Station 1	0.087	0.005	0.042	0.088	0.005	0.042
Station 2	0.087	0.005	0.042	0.095	0.005	0.042
Station 3	0.099	0.005	0.042	0.107	0.005	0.042
Station 4	0.097	0.005	0.042	0.118	0.006	0.045
Station 5	0.082	0.005	0.042	0.102	0.005	0.042
Station 6	0.081	0.005	0.042	0.105	0.005	0.042
Station 7	0.083	0.005	0.042	0.095	0.006	0.042
Station 8	0.082	0.005	0.042	0.093	0.006	0.042
Station 9	0.081	0.005	0.042	0.093	0.005	0.042
Station 10	0.081	0.005	0.042	0.092	0.005	0.042

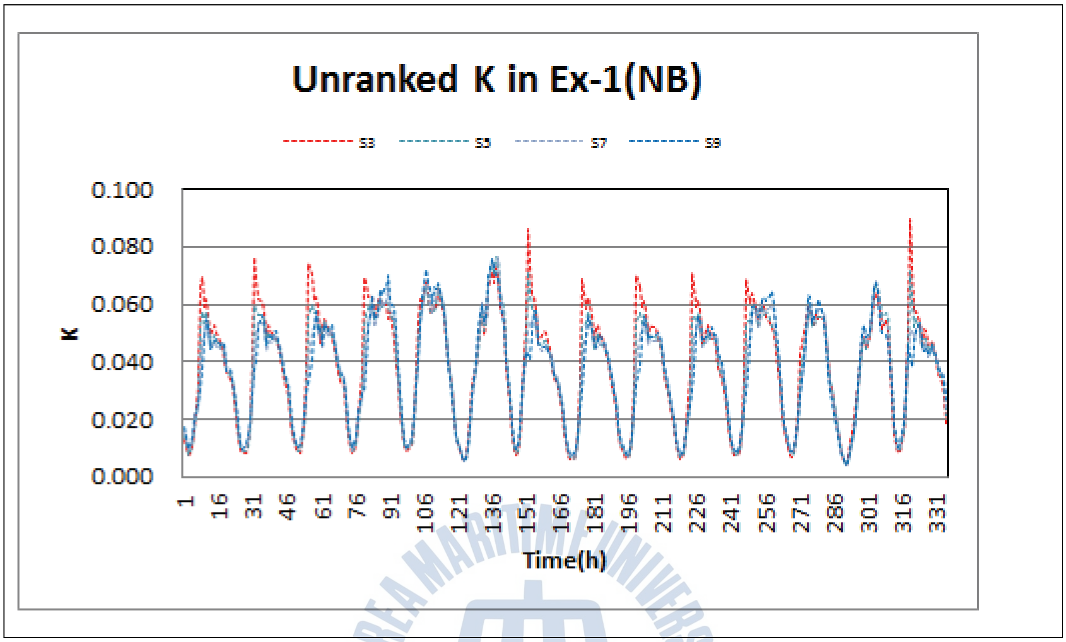


Figure 4.14 Unranked K in expressway Ex-1(NB)

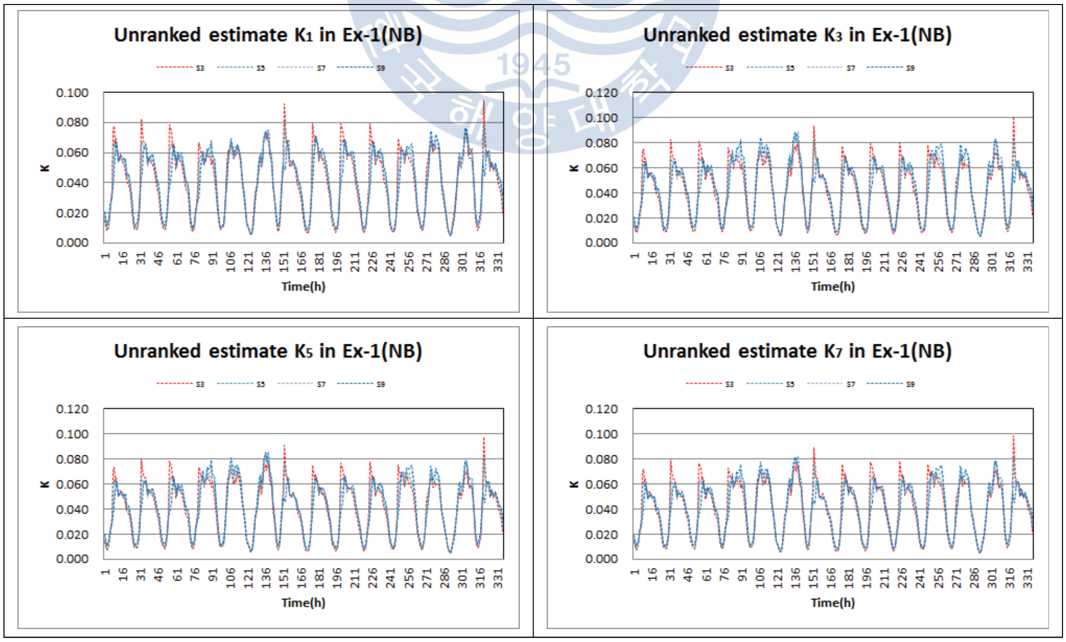


Figure 4.15 Unranked estimate K_j in expressway Ex-1(NB)

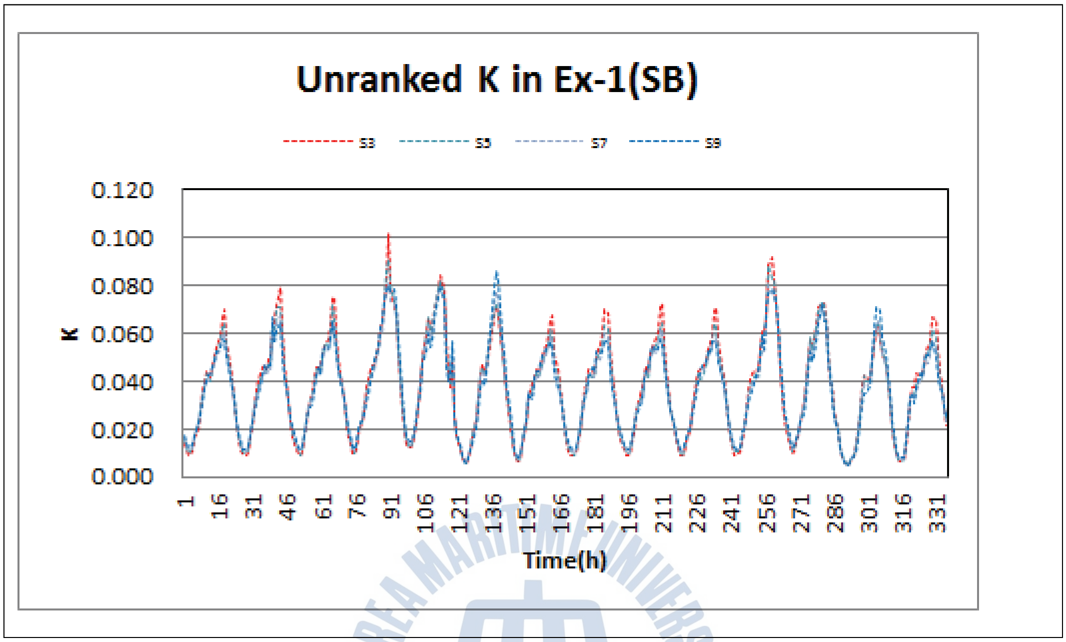


Figure 4.16 Unranked K in expressway Ex-1(SB)

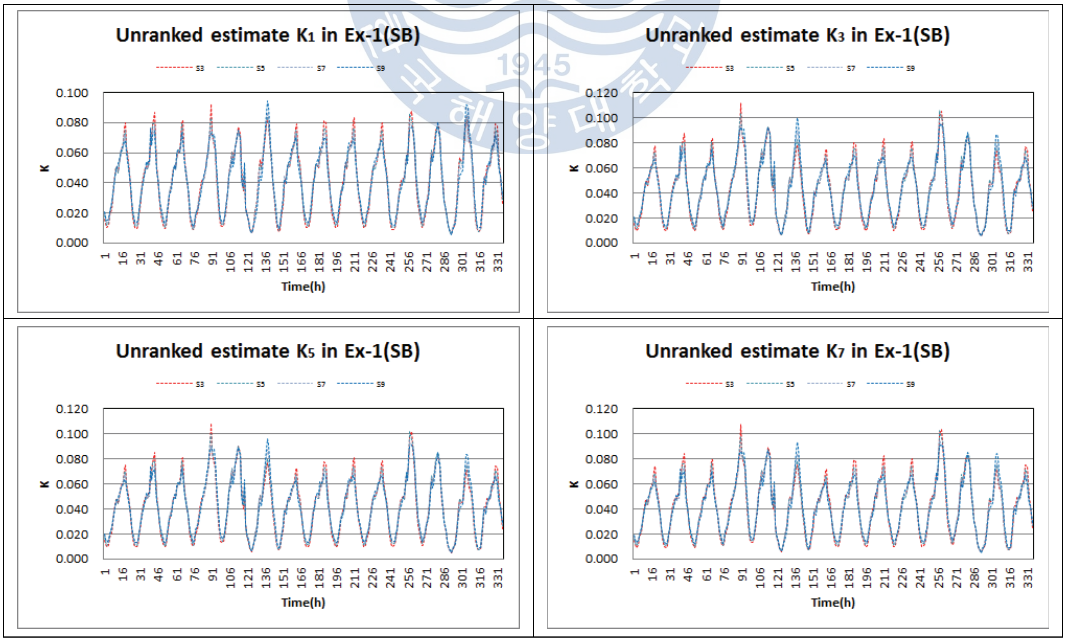


Figure 4.17 Unranked estimate K_j in expressway Ex-1(SB)

4.3.2 Ranked hourly proportion of K and estimate K_j

The hourly proportion distributions of K and estimate K_j in expressway Ex-1 appeared to be a considerable difference when K was only ranked K at the stations in expressway Ex-1, but those distributions of K and estimate K_j appeared to be a clear difference when both K and estimate K_j were ranked at the stations in expressway Ex-1 as shown in **Figures 4.18~4.25**.

Particularly when compared with the hourly proportions between ranked K and unranked estimate K_j at the stations in expressway Ex-1, the hourly proportions of ranked K appeared to be in the lower part than those of unranked estimate K_j showing the similar distributions in the hourly proportions of unranked estimate K_j at the stations 3, 5, 7, and 9 in NB and SB as shown in **Figures 4.18~4.21**.

Also when compared with the hourly proportions between ranked K and ranked estimate K_j at the stations in expressway Ex-1, the hourly proportions of ranked K appeared to be close with those of ranked estimates K_1 and K_7 showing the similar distributions in the hourly proportions of ranked estimate K_j in NB and SB as shown in **Figures 4.22~4.25**.

So, the correlative analysis between K and estimate K_j when both K and estimate K_j were ranked at the stations in expressway Ex-1 seemed to need to be performed for determining the estimate K_j that could fit well with K.

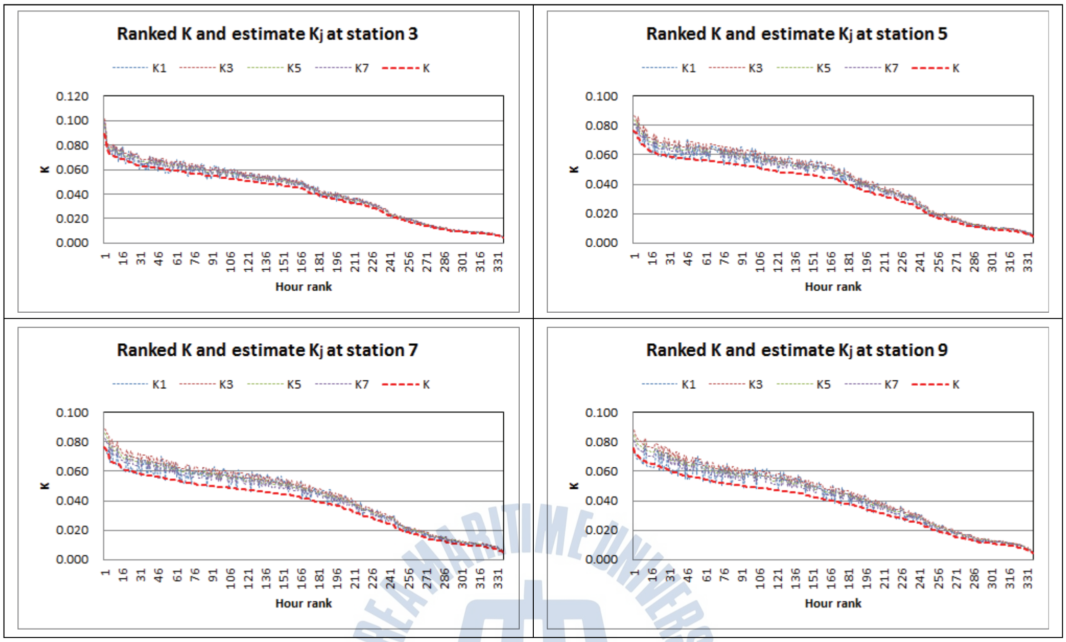


Figure 4.18 Ranked K and unranked estimate K_j in expressway Ex-1(NB)

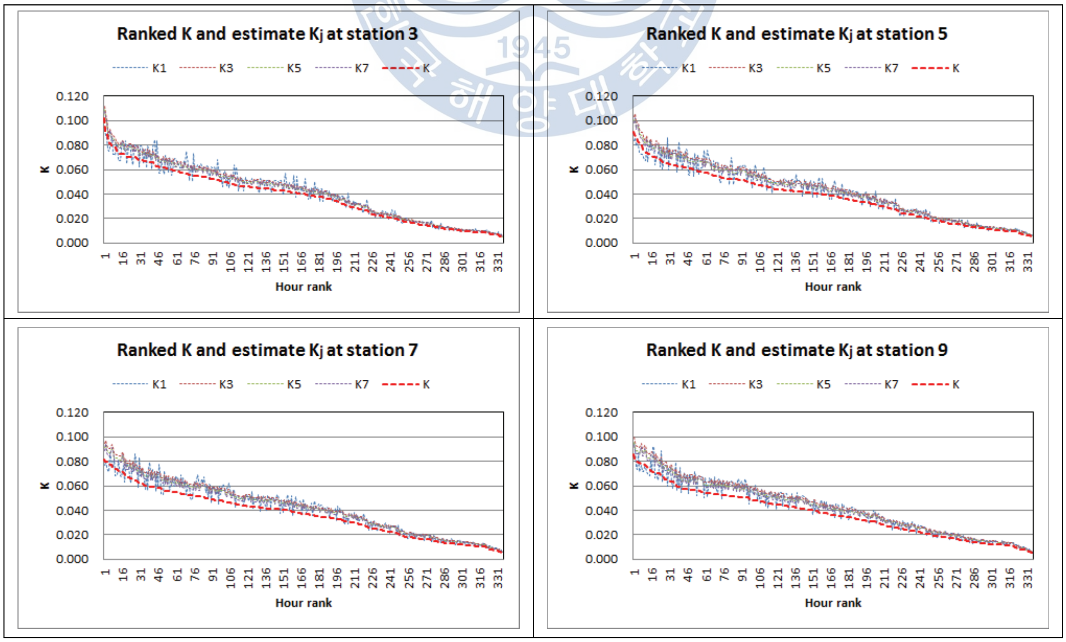


Figure 4.19 Ranked K and unranked estimate K_j in expressway Ex-1(SB)

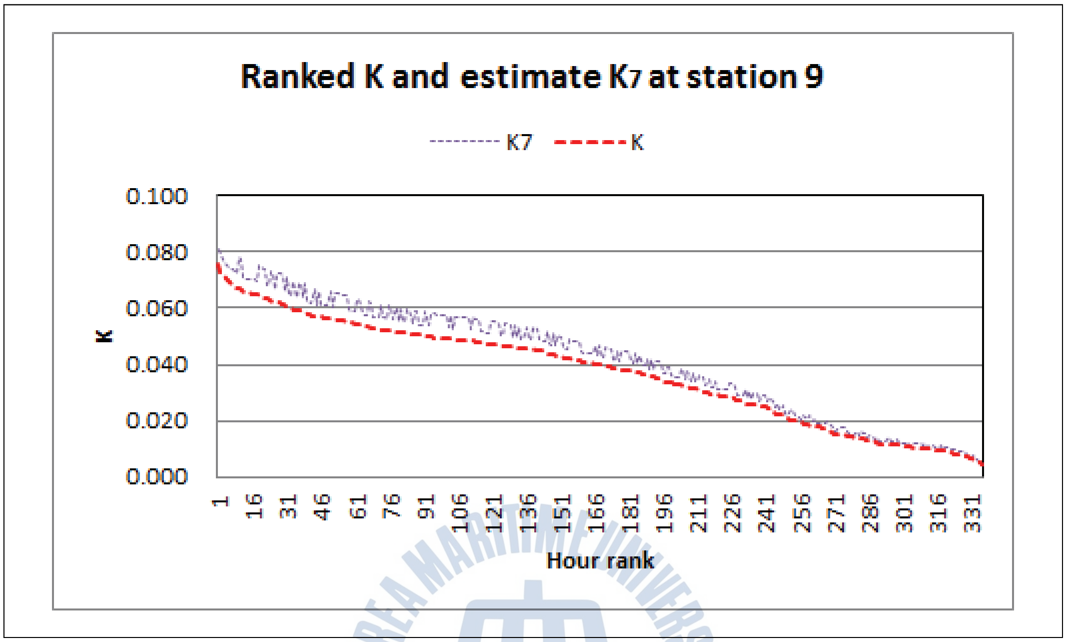


Figure 4.20 Ranked K and unranked estimate K_7 in expressway Ex-1(NB)

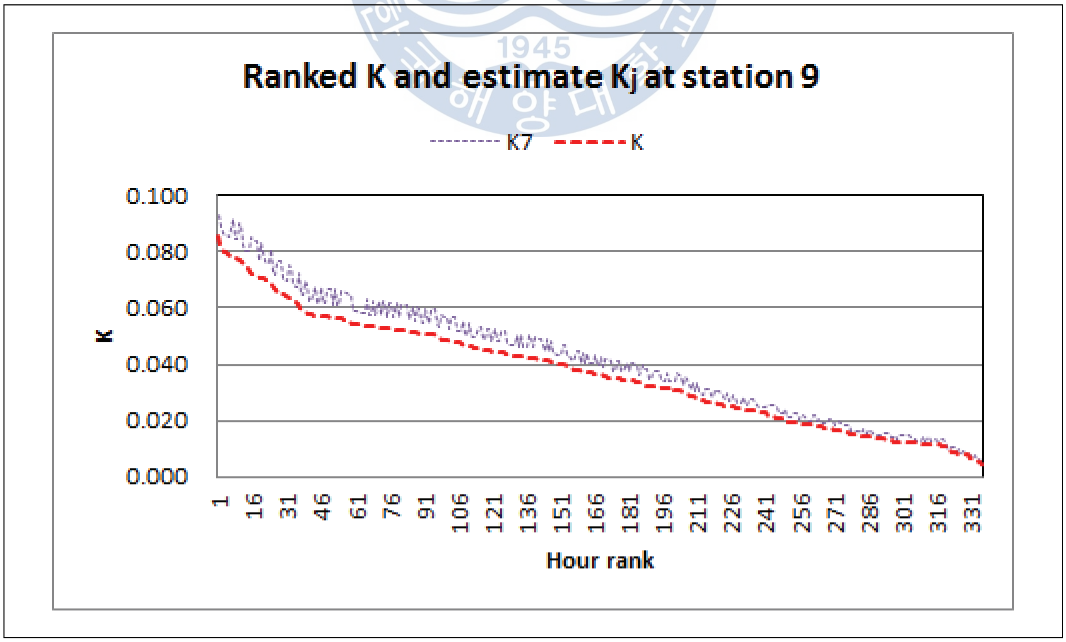


Figure 4.21 Ranked K and unranked estimate K_7 in expressway Ex-1(SB)

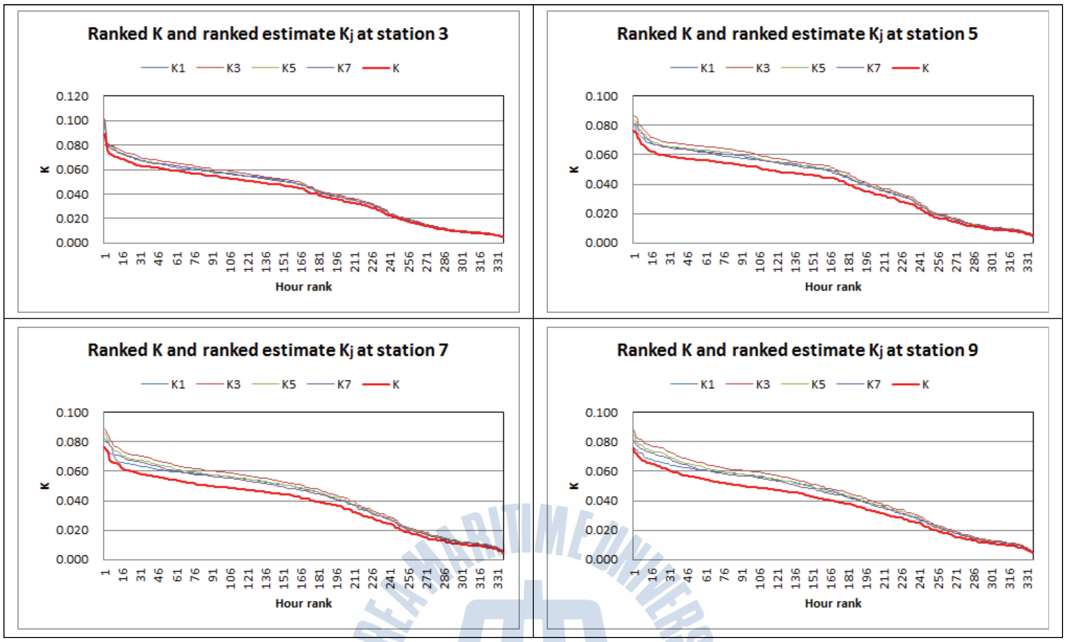


Figure 4.22 Ranked K and ranked estimate K_j in expressway Ex-1(NB)

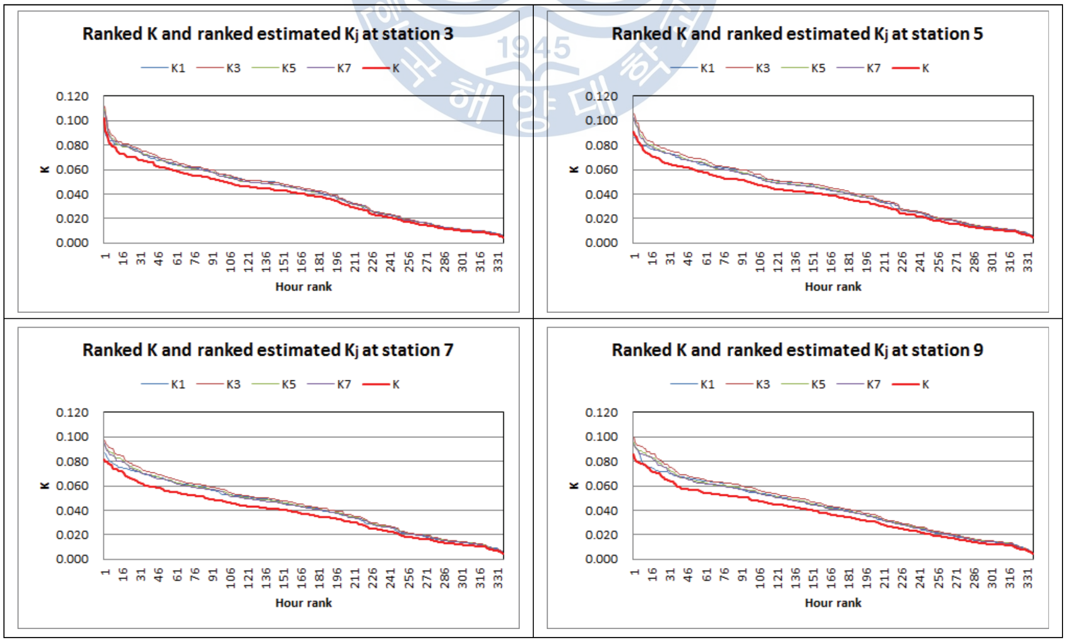


Figure 4.23 Ranked K and ranked estimate K_j in expressway Ex-1(SB)

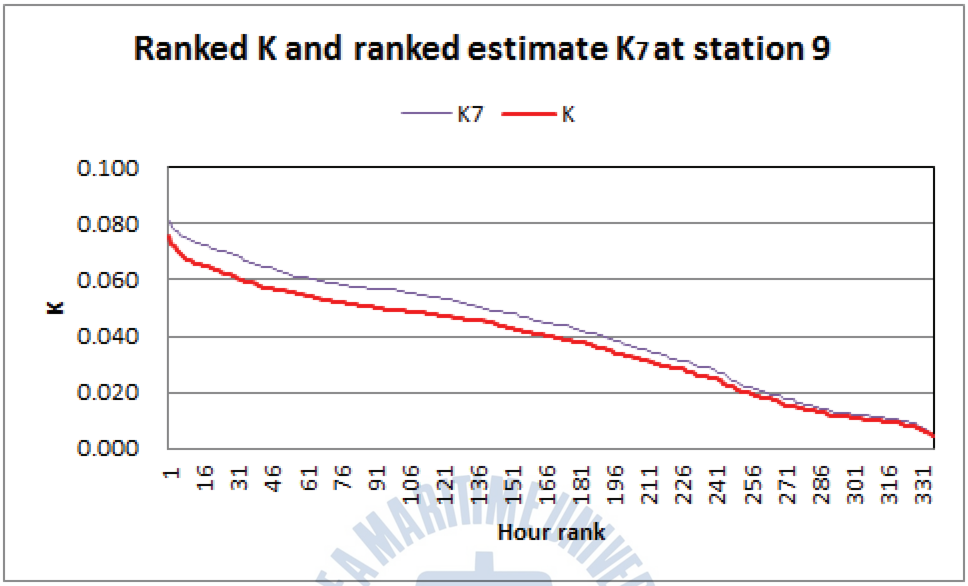


Figure 4.24 Ranked K and ranked estimate K_7 in expressway Ex-1(NB)

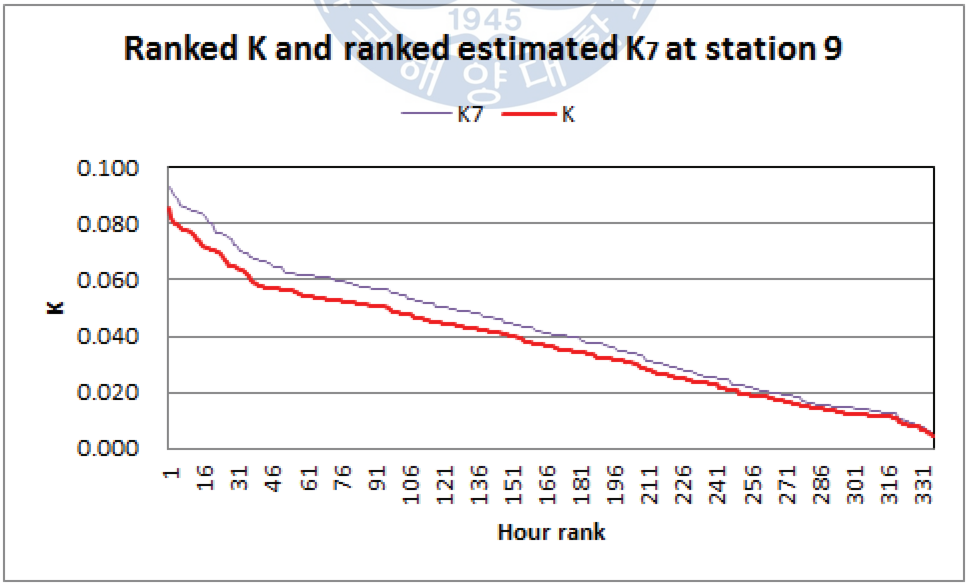


Figure 4.25 Ranked K and ranked estimate K_7 in expressway Ex-1(SB)

As a result, the highest hourly proportions of K and estimate K_j appeared to show a large variation with the range of about 0.06 to 0.15 showing the rural and urban traffic flow characteristics in the rural expressways. Also, the hourly proportions of K and estimate K_j appeared to show a considerable difference at the stations of the expressways before and after ranked process. So, the modeling process between the hourly proportions of K and estimate K_j in expressways Ex-10 and Ex-1 seemed to need to be performed for determining the estimate K_j that could fit well with the hourly proportions of K on the basis of the proper range of interval of K.

5. Model Development and Verification

5.1 Model development

The hourly volume factor(K) could be found by the hourly proportion of annual average daily traffic(AADT) of the year for an hour, but the estimate K_j could be found by the hourly proportion of average daily traffic(ADT) for a short-term period. Under the assumption that the hourly volume factor(K) in the basic expressway segment would be positively correlated by the estimate K_j as summarized in **Tables 5.1~5.2**, the hourly volume factor(K) could be expressed by the function of the estimate K_j as follows;

$$K = f(K_j) \quad (5.\ 1)$$

where, K : hourly volume factor

K_j : estimate j of hourly volume factor(j=1, 3, 5, and 7)

Table 5.1 Correlation coefficients between K and estimate K_j in expressway Ex-10

Station \ Direction		EB				WB			
		K_1	K_3	K_5	K_7	K_1	K_3	K_5	K_7
K	Station 1	0.985	1.000	1.000	1.000	0.990	1.000	1.000	0.999
	Station 2	0.991	1.000	1.000	1.000	0.987	1.000	1.000	0.999
	Station 3	0.987	1.000	1.000	1.000	0.991	1.000	1.000	1.000
	Station 4	0.986	1.000	1.000	1.000	0.991	1.000	1.000	1.000
	Station 5	0.987	1.000	1.000	1.000	0.992	1.000	1.000	1.000
	Station 6	0.992	1.000	1.000	1.000	0.986	1.000	1.000	1.000
	Station 7	0.986	1.000	1.000	1.000	0.991	1.000	1.000	1.000
	Station 8	0.988	1.000	1.000	1.000	0.994	1.000	1.000	1.000
	Station 9	0.991	1.000	1.000	1.000	0.995	1.000	1.000	1.000
	Station 10	0.996	1.000	1.000	1.000	0.991	1.000	1.000	1.000

Table 5.2 Correlation coefficients between K and estimate K_j in expressway Ex-1

Station \ Direction		NB				SB			
		K_1	K_3	K_5	K_7	K_1	K_3	K_5	K_7
K	Station 1	0.999	1.000	1.000	1.000	0.997	1.000	1.000	1.000
	Station 2	0.999	1.000	1.000	1.000	0.998	1.000	1.000	1.000
	Station 3	1.000	1.000	1.000	1.000	0.997	1.000	1.000	1.000
	Station 4	0.999	1.000	1.000	1.000	0.997	1.000	1.000	0.999
	Station 5	0.999	1.000	1.000	1.000	0.996	1.000	1.000	1.000
	Station 6	0.999	1.000	1.000	1.000	0.995	1.000	1.000	1.000
	Station 7	0.997	1.000	1.000	0.999	0.997	1.000	1.000	0.999
	Station 8	0.997	1.000	1.000	0.999	0.997	1.000	1.000	1.000
	Station 9	0.996	1.000	1.000	1.000	0.995	1.000	1.000	0.997
	Station 10	0.996	1.000	1.000	1.000	0.997	1.000	1.000	1.000

According to the analyses of hourly volume factor(K) and estimate K_j in Chapter 4, the highest hourly proportions of K in expressway Ex-10 were distributed in the range of about 0.109 to 0.148 showing the rural traffic flow characteristics, but those proportions of K in expressway Ex-1 were distributed in the range of about 0.068 to 0.102 lower than in expressway Ex-10 showing the urban traffic flow characteristics. So, for determining the model of estimate K_j that could fit well with the highest hourly proportions of K, the highest hourly proportions of K were classified into 9 ranges of interval; $0.06 \leq K < 0.07$, $0.07 \leq K < 0.08$, $0.08 \leq K < 0.09$, $0.09 \leq K < 0.10$, $0.10 \leq K < 0.11$, $0.11 \leq K < 0.12$, $0.12 \leq K < 0.13$, $0.13 \leq K < 0.14$, and $0.14 \leq K < 0.15$. Also, the linear and curve-linear regression models were examined between K and estimate K_j for each range of interval. On the basis of the high coefficient of determination(R^2), the appropriate models appeared to be linear(LIN), quadratic(QUA), cubic(CUB), and power(POW) functions with hourly volume factor(K) as a dependent variable and estimate K_j as an independent one as follows;

LIN : $K = \beta_0 + \beta_1 \times K_j$ (5. 2)

QUA : $K = \beta_0 + \beta_1 \times K_j + \beta_2 \times K_j^2$ (5. 3)

CUB : $K = \beta_0 + \beta_1 \times K_j + \beta_2 \times K_j^2 + \beta_3 \times K_j^3$ (5. 4)

POW : $K = \beta_0 \times K_j^{\beta_1}$ (5. 5)

Where, β_i : regression coefficients($i = 0, 1, 2, 3$)

Regression analysis was used to build the hourly volume factor(K) model with the estimate K_j for the purpose of identifying the important independent variables with the high criteria of R^2.

Table 5.3 Regression models for predicting K in $0.06 \le K < 0.07$

Estimate	Model		R^2	F-sig.
K_1	**LIN**	$K = -0.00001415 + 0.75 \times K_1$	0.973	0.000
	QUA	$K = -0.00005567 + 0.753 \times K_1 - 0.04 \times K_1^2$	0.973	0.000
	CUB	$K = 0.00008017 + 0.737 \times K_1 + 0.421 \times K_1^2 - 3.758 \times K_1^3$	0.973	0.000
	POW	$K = 0.746 \times K_1^{0.999}$	0.989	0.000
K_3	**LIN**	$K = 0.0000004814 + 0.709 \times K_3$	0.996	0.000
	QUA	$K = 0.0006139 + 0.705 \times K_3 + 0.051 \times K_3^2$	0.996	0.000
	CUB	$K = 0.74 \times K_3 - 0.859 \times K_3^2 + 6.831 \times K_3^3$	0.996	0.000
	POW	$K = 0.711 \times K_3^{1.001}$	0.998	0.000
K_5	**LIN**	$K = -0.00002075 + 0.74 \times K_5$	0.997	0.000
	QUA	$K = 0.00008931 + 0.732 \times K_5 + 0.1 \times K_5^2$	0.997	0.000
	CUB	$K = 0.766 \times K_5 - 0.833 \times K_5^2 + 7.293 \times K_5^3$	0.997	0.000
	POW	$K = 0.742 \times K_5^{1.001}$	0.999	0.000
K_7	**LIN**	$K = 0.00003137 + 0.749 \times K_7$	0.993	0.000
	QUA	$K = 0.00001466 + 0.75 \times K_7 - 0.016 \times K_7^2$	0.993	0.000
	CUB	$K = 0.786 \times K_7 - 1.013 \times K_7^2 + 7.918 \times K_7^3$	0.993	0.000
	POW	$K = 0.751 \times K_7^{1.001}$	0.999	0.000

Note: **LIN**, **QUA**, **CUB** and **POW** means linear, quadratic, cubic and power functions between K and estimates K_1, K_3, K_5, and K_7, respectively.

0.000 in F-sig. means that the probability of significance is 0.000<0.05, and independent variables are significantly correlated with dependent ones.

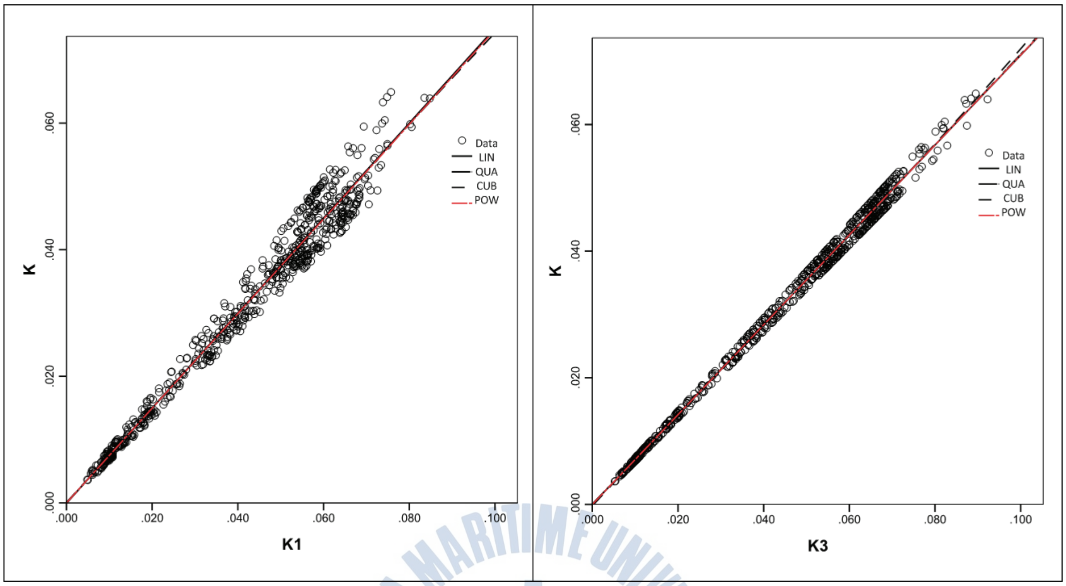


Figure 5.1 K predictive models by K_1 and K_3 in $0.06 \leq K < 0.07$

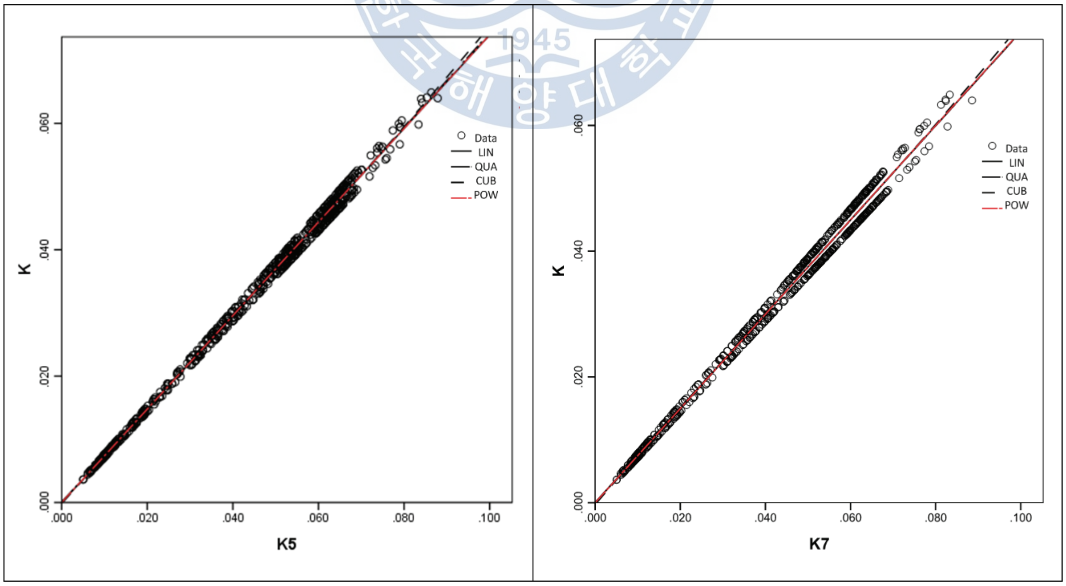


Figure 5.2 K predictive models by K_5 and K_7 in $0.06 \leq K < 0.07$

Table 5.4 Regression models for predicting K in $0.07 \le K < 0.08$

Estimate	Model		R^2	F-sig.
K_1	**LIN**	$K = -0.001 + 0.918 \times K_1$	0.992	0.000
	QUA	$K = 0.003 + 0.647 \times K_1 + 3.507 \times K_1^2$	0.996	0.000
	CUB	$K = -0.002 + 1.242 \times K_1 - 13.735 \times K_1^2 + 143.834 \times K_1^3$	0.998	0.000
	POW	$K = 0.903 \times K_1^{1.004}$	0.997	0.000
K_3	**LIN**	$K = -0.00008745 + 0.837 \times K_3$	0.999	0.000
	QUA	$K = 0.816 \times K_3 + 0.244 \times K_3^2$	1.000	0.000
	CUB	$K = -0.001 + 0.913 \times K_3 - 2.256 \times K_3^2 + 18.414 \times K_3^3$	1.000	0.000
	POW	$K = 0.84 \times K_3^{1.002}$	1.000	0.000
K_5	**LIN**	$K = -0.00008118 + 0.875 \times K_5$	1.000	0.000
	QUA	$K = 0.855 \times K_5 + 0.237 \times K_5^2$	1.000	0.000
	CUB	$K = -0.001 + 0.94 \times K_5 - 2.033 \times K_5^2 + 17.448 \times K_5^3$	1.000	0.000
	POW	$K = 0.878 \times K_5^{1.002}$	1.000	0.000
K_7	**LIN**	$K = -0.00007963 + 0.895 \times K_7$	0.999	0.000
	QUA	$K = 0.871 \times K_7 + 0.307 \times K_7^2$	0.999	0.000
	CUB	$K = -0.001 + 1.016 \times K_7 - 3.696 \times K_7^2 + 31.676 \times K_7^3$	0.999	0.000
	POW	$K = 0.901 \times K_7^{1.003}$	0.999	0.000

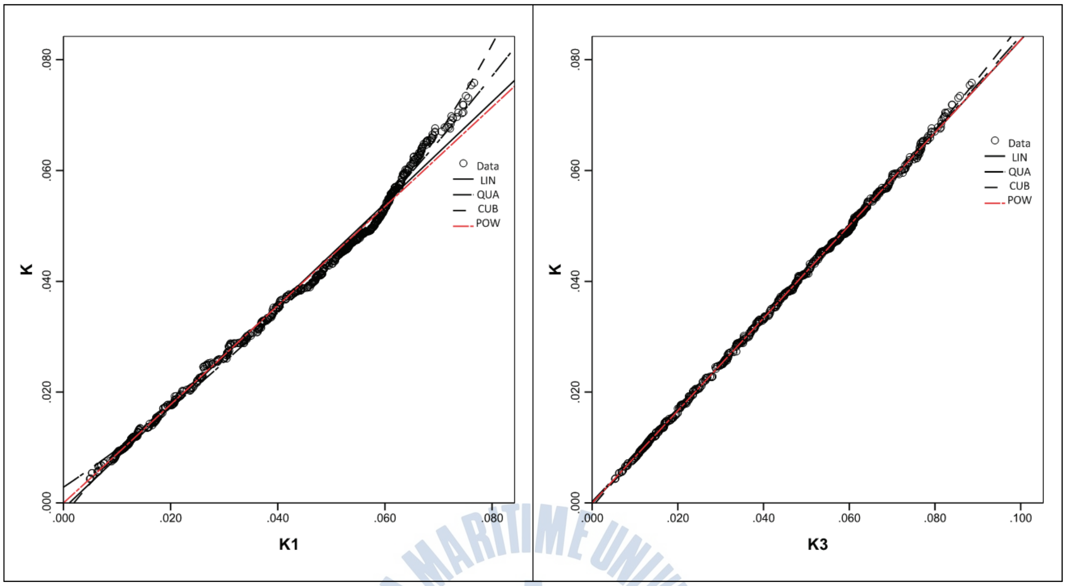


Figure 5.3 K predictive models by K_1 and K_3 in $0.07 \le K < 0.08$

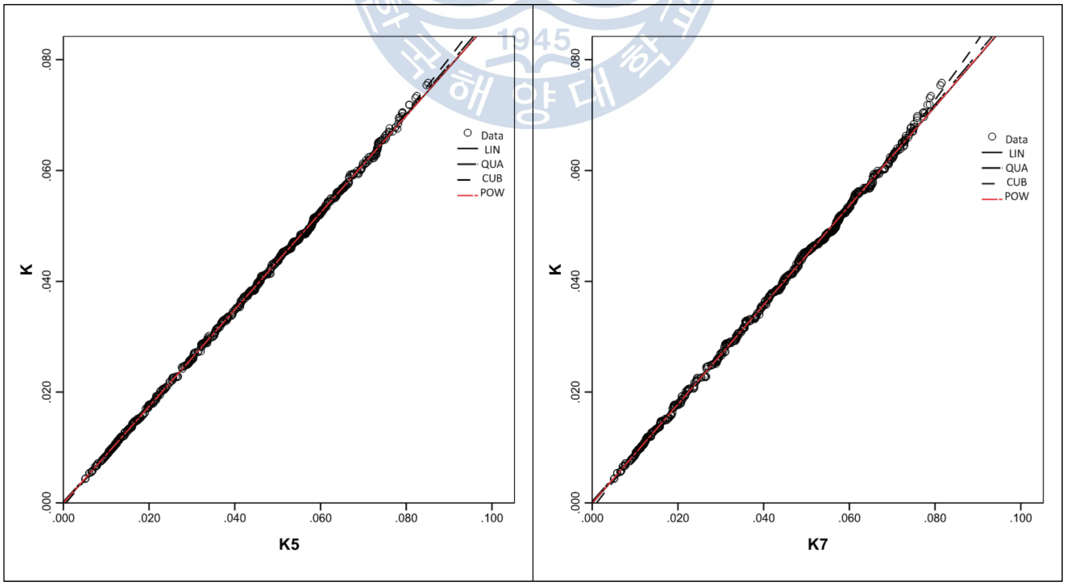


Figure 5.4 K predictive models by K_5 and K_7 in $0.07 \le K < 0.08$

Table 5.5 Regression models for predicting K in $0.08 \leq K < 0.09$

Estimate	Model		R^2	F-sig.
K_1	**LIN**	$K = 0.94 \times K_1$	0.999	0.000
	QUA	$K = 0.000003579 + 0.928 \times K_1 + 0.158 \times K_1^2$	0.999	0.000
	CUB	$K = 0.001 + 0.868 \times K_1 + 1.767 \times K_1^2 - 12.201 \times K_1^3$	0.999	0.000
	POW	$K = 0.947 \times K_1^{1.004}$	0.999	0.000
K_3	**LIN**	$K = -0.00005147 + 0.906 \times K_3$	1.000	0.000
	QUA	$K = 0.00008726 + 0.896 \times K_3 + 0.118 \times K_3^2$	1.000	0.000
	CUB	$K = 0.00008489 + 0.896 \times K_3 + 0.111 \times K_3^2 + 0.051 \times K_3^3$	1.000	0.000
	POW	$K = 0.907 \times K_3^{1.001}$	1.000	0.000
K_5	**LIN**	$K = -0.00004851 + 0.936 \times K_5$	1.000	0.000
	QUA	$K = 0.00008241 + 0.927 \times K_5 + 0.119 \times K_5^2$	1.000	0.000
	CUB	$K = 0.00006343 + 0.929 \times K_5 + 0.059 \times K_5^2 + 0.454 \times K_5^3$	1.000	0.000
	POW	$K = 0.938 \times K_5^{1.001}$	1.000	0.000
K_7	**LIN**	$K = -0.00004591 + 0.937 \times K_7$	0.999	0.000
	QUA	$K = 0.00007514 + 0.929 \times K_7 + 0.11 \times K_7^2$	0.999	0.000
	CUB	$K = 0.921 \times K_7 + 0.31 \times K_7^2 - 1.515 \times K_7^3$	0.999	0.000
	POW	$K = 0.94 \times K_7^{1.001}$	1.000	0.000

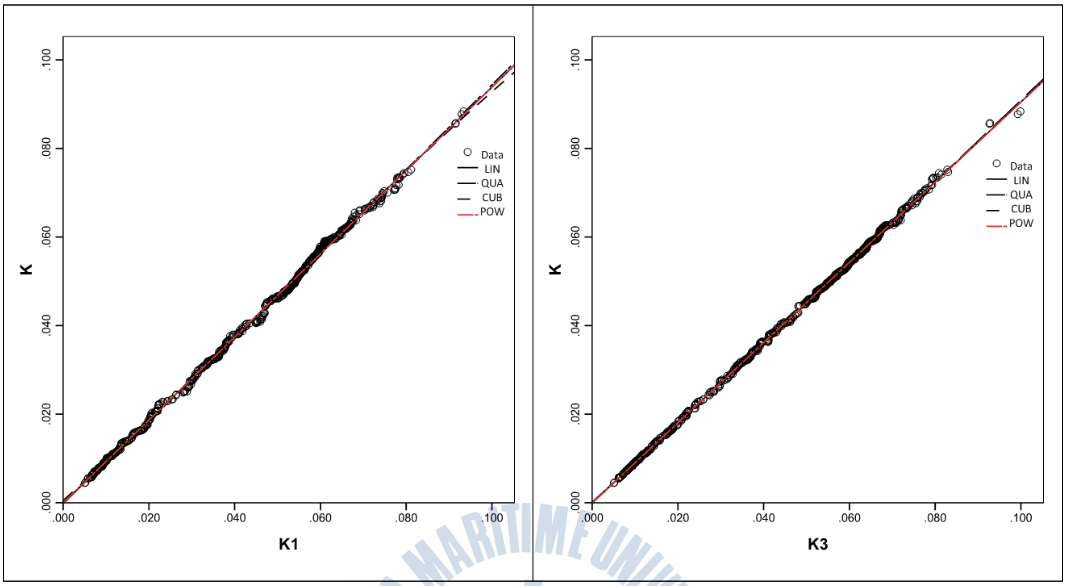


Figure 5.5 K predictive models by K_1 and K_3 in $0.08 \leq K < 0.09$

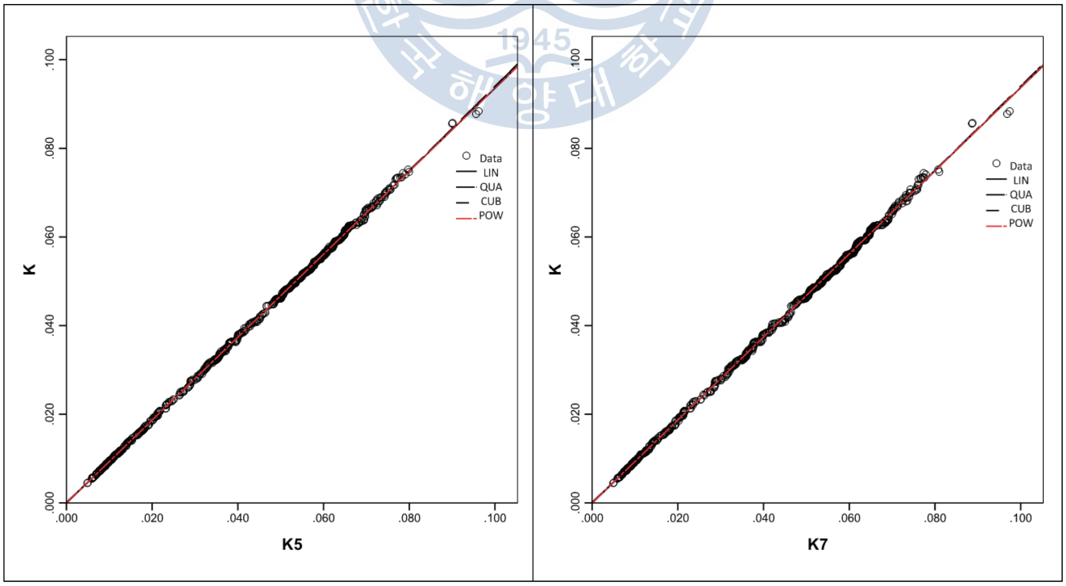


Figure 5.6 K predictive models by K_5 and K_7 in $0.08 \leq K < 0.09$

Table 5.6 Regression models for predicting K in $0.09 \le K < 0.10$

Estimate	Model		R^2	F-sig.
K_1	**LIN**	$K = -0.001 + 0.912 \times K_1$	0.992	0.000
	QUA	$K = 0.001 + 0.776 \times K_1 + 1.6 \times K_1^2$	0.994	0.000
	CUB	$K = -0.003 + 1.206 \times K_1 - 9.619 \times K_1^2 + 82.384 \times K_1^3$	0.995	0.000
	POW	$K = 0.93 \times K_1^{1.013}$	0.997	0.000
K_3	**LIN**	$K = -0.00004394 + 0.87 \times K_3$	0.998	0.000
	QUA	$K = 0.00002944 + 0.865 \times K_3 + 0.049 \times K_3^2$	0.998	0.000
	CUB	$K = 0.00004185 + 0.864 \times K_3 + 0.078 \times K_3^2 - 0.194 \times K_3^3$	0.998	0.000
	POW	$K = 0.871 \times K_3^{1.001}$	0.999	0.000
K_5	**LIN**	$K = -0.00004685 + 0.898 \times K_5$	0.998	0.000
	QUA	$K = 0.00003241 + 0.893 \times K_5 + 0.057 \times K_5^2$	0.998	0.000
	CUB	$K = 0.00004244 + 0.892 \times K_5 + 0.082 \times K_5^2 - 0.173 \times K_5^3$	0.998	0.000
	POW	$K = 0.899 \times K_5^{1.001}$	0.999	0.000
K_7	**LIN**	$K = -0.00005191 + 0.897 \times K_7$	0.998	0.000
	QUA	$K = 0.00002962 + 0.892 \times K_7 + 0.058 \times K_7^2$	0.998	0.000
	CUB	$K = 0.00006474 + 0.889 \times K_7 + 0.146 \times K_7^2 - 0.601 \times K_7^3$	0.998	0.000
	POW	$K = 0.899 \times K_7^{1.001}$	0.999	0.000

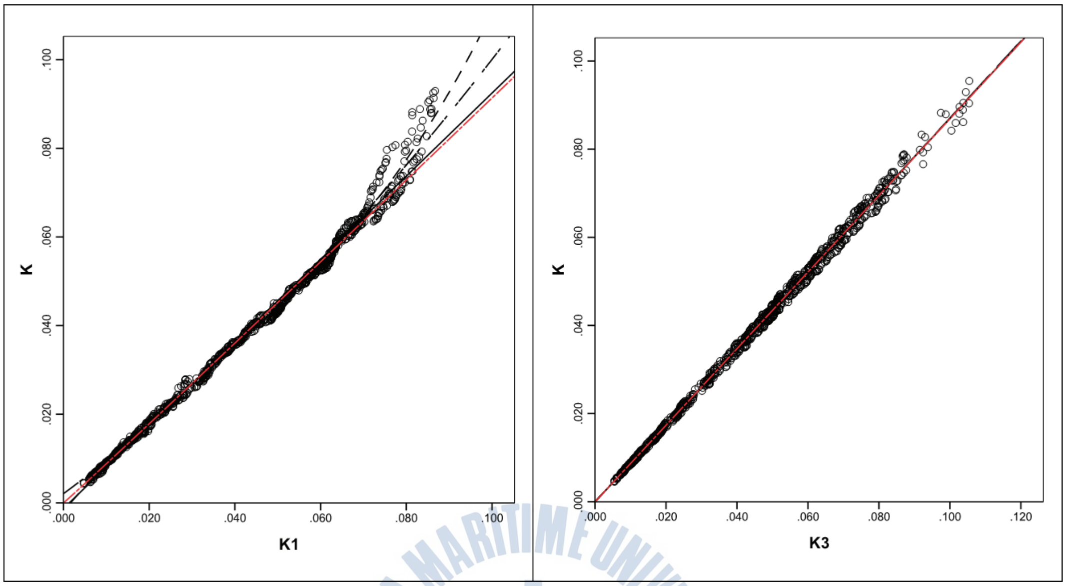


Figure 5.7 K predictive models by K_1 and K_3 in $0.09 \leq$ K < 0.10

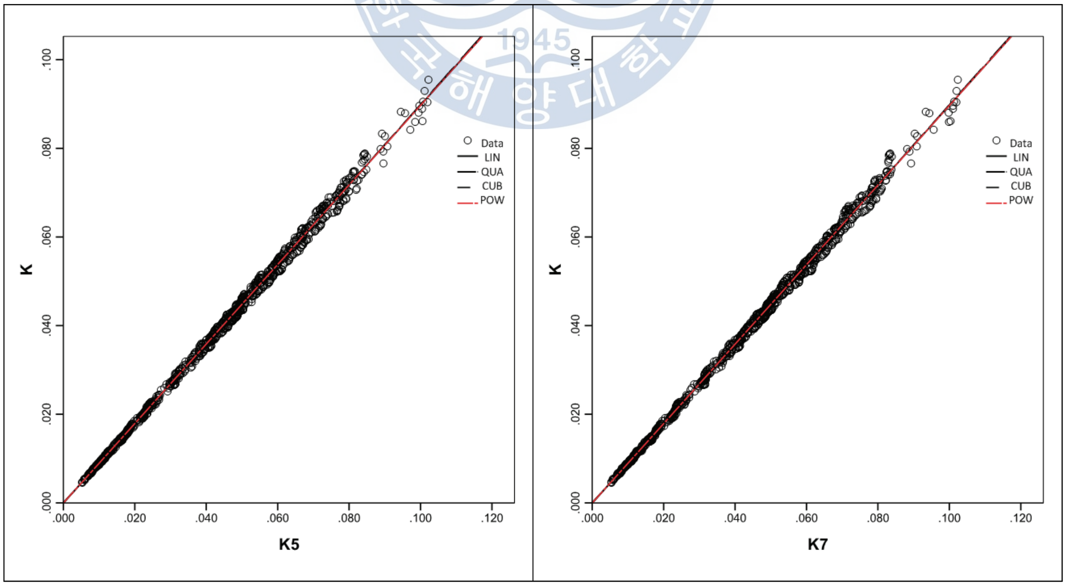


Figure 5.8 K predictive models by K_5 and K_7 in $0.09 \leq$ K < 0.10

Table 5.7 Regression models for predicting K in $0.10 \le K < 0.11$

Estimate	Model		R^2	F-sig.
K_1	**LIN**	$K = -0.001 + 0.937 \times K_1$	0.993	0.000
	QUA	$K = 0.002 + 0.767 \times K_1 + 1.974 \times K_1^2$	0.995	0.000
	CUB	$K = -0.003 + 1.269 \times K_1 - 10.971 \times K_1^2 + 94.113 \times K_1^3$	0.997	0.000
	POW	$K = 0.953 \times K_1^{1.013}$	0.997	0.000
K_3	**LIN**	$K = -0.00006045 + 0.884 \times K_3$	0.999	0.000
	QUA	$K = 0.00005866 + 0.877 \times K_3 + 0.075 \times K_3^2$	0.999	0.000
	CUB	$K = -0.00004993 + 0.887 \times K_3 - 0.163 \times K_3^2 + 1.527 \times K_3^3$	0.999	0.000
	POW	$K = 0.885 \times K_3^{1.001}$	1.000	0.000
K_5	**LIN**	$K = -0.00006371 + 0.916 \times K_5$	1.000	0.000
	QUA	$K = 0.00006597 + 0.908 \times K_5 + 0.088 \times K_5^2$	1.000	0.000
	CUB	$K = -0.00004914 + 0.919 \times K_5 - 0.183 \times K_5^2 + 1.799 \times K_5^3$	1.000	0.000
	POW	$K = 0.917 \times K_5^{1.001}$	1.000	0.000
K_7	**LIN**	$K = -0.00006784 + 0.918 \times K_7$	0.999	0.000
	QUA	$K = 0.0000876 + 0.909 \times K_7 + 0.106 \times K_7^2$	0.999	0.000
	CUB	$K = 0.928 \times K_7 - 0.363 \times K_7^2 + 3.126 \times K_7^3$	0.999	0.000
	POW	$K = 0.92 \times K_7^{1.001}$	1.000	0.000

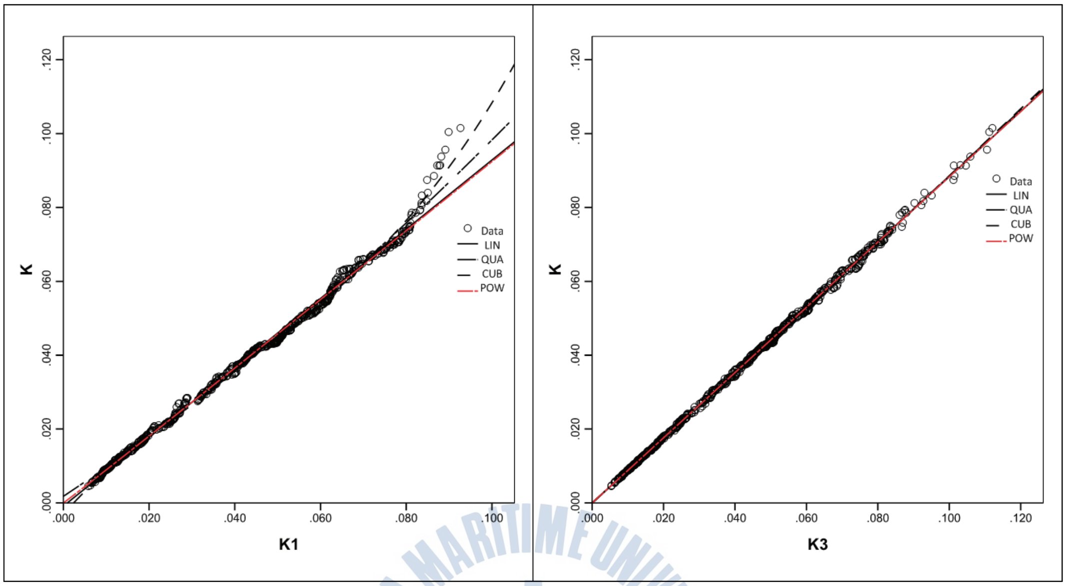


Figure 5.9 K predictive models by K_1 and K_3 in $0.10 \leq K < 0.11$

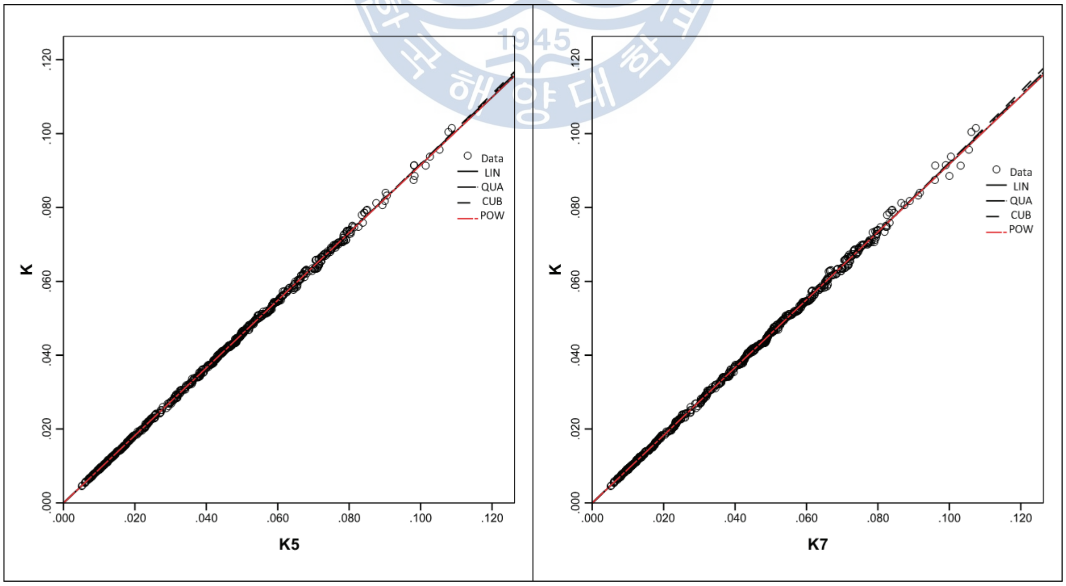


Figure 5.10 K predictive models by K_5 and K_7 in $0.10 \leq K < 0.11$

Table 5.8 Regression models for predicting K in $0.11 \le K < 0.12$

Estimate	Model		R^2	F-sig.
K_1	**LIN**	$K = -0.002 + 1.098 \times K_1$	0.982	0.000
	QUA	$K = 0.004 + 0.632 \times K_1 + 5.875 \times K_1^2$	0.991	0.000
	CUB	$K = -0.002 + 1.427 \times K_1 - 16.356 \times K_1^2 + 174.129 \times K_1^3$	0.995	0.000
	POW	$K = 1.081 \times K_1^{1.012}$	0.996	0.000
K_3	**LIN**	$K = 0.944 \times K_3$	1.000	0.000
	QUA	$K = 0.923 \times K_3 + 0.222 \times K_3^2$	1.000	0.000
	CUB	$K = 0.96 \times K_3 - 0.601 \times K_3^2 + 4.961 \times K_3^3$	1.000	0.000
	POW	$K = 0.945 \times K_3^{1.001}$	1.000	0.000
K_5	**LIN**	$K = 0.995 \times K_5$	0.999	0.000
	QUA	$K = 0.964 \times K_5 + 0.342 \times K_5^2$	0.999	0.000
	CUB	$K = 1.009 \times K_5 - 0.696 \times K_5^2 + 6.62 \times K_5^3$	0.999	0.000
	POW	$K = 0.993 \times K_5^{1.001}$	1.000	0.000
K_7	**LIN**	$K = 1.052 \times K_7$	0.999	0.000
	QUA	$K = 1.012 \times K_7 + 0.457 \times K_7^2$	0.999	0.000
	CUB	$K = -0.001 + 1.112 \times K_7 - 2.01 \times K_7^2 + 16.797 \times K_7^3$	0.999	0.000
	POW	$K = 1.054 \times K_7^{1.002}$	0.999	0.000

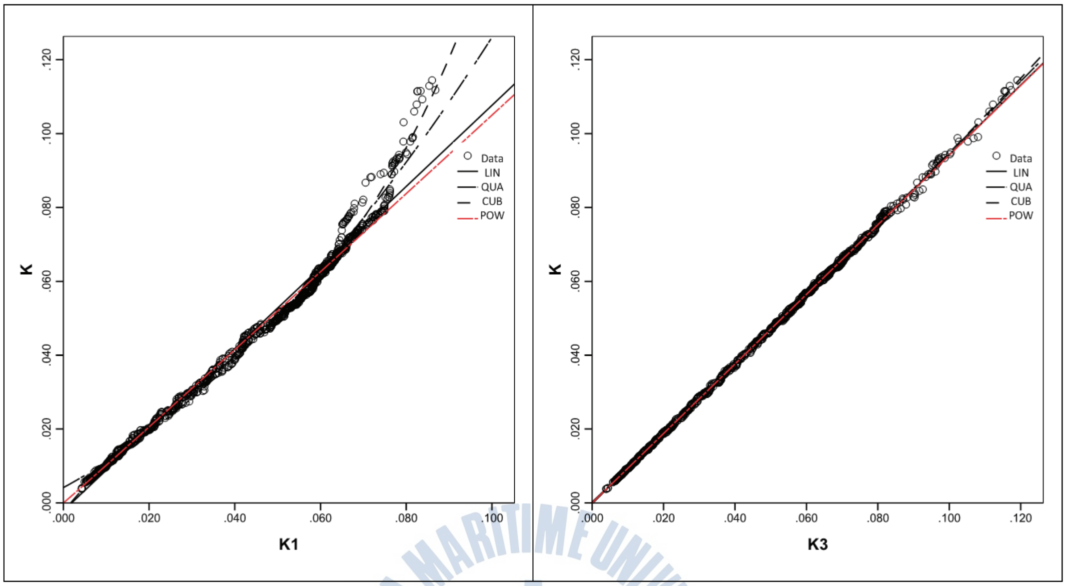


Figure 5.11 K predictive models by K_1 and K_3 in $0.11 \leq K < 0.12$

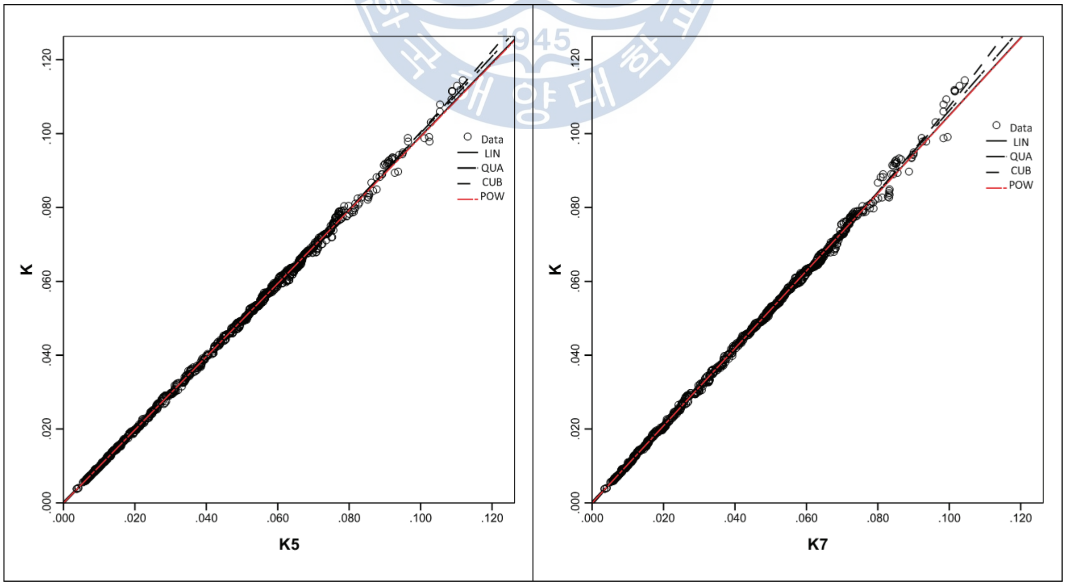


Figure 5.12 K predictive models by K_5 and K_7 in $0.11 \leq K < 0.12$

Table 5.9 Regression models for predicting K in $0.12 \le K < 0.13$

Estimate	Model		R^2	F-sig.
K_1	LIN	$K = -0.00007636 + 1.064 \times K_1$	0.916	0.000
	QUA	$K = -0.00007391 + 1.063 \times K_1 + 0.002 \times K_1^2$	0.916	0.000
	CUB	$K = 0.001 + 0.912 \times K_1 + 4.224 \times K_1^2 - 32.46 \times K_1^3$	0.916	0.000
	POW	$K = 1.048 \times K_1^{0.999}$	0.974	0.000
K_3	LIN	$K = -0.00007965 + 0.958 \times K_3$	0.998	0.000
	QUA	$K = 0.943 \times K_3 + 0.158 \times K_3^2$	0.998	0.000
	CUB	$K = 0.978 \times K_3 - 0.602 \times K_3^2 + 4.461 \times K_3^3$	0.998	0.000
	POW	$K = 0.958 \times K_3^{1.001}$	0.999	0.000
K_5	LIN	$K = -0.0000803 + 1.008 \times K_5$	0.998	0.000
	QUA	$K = 0.991 \times K_5 + 0.187 \times K_5^2$	0.998	0.000
	CUB	$K = 1.034 \times K_5 - 0.788 \times K_5^2 + 6.036 \times K_5^3$	0.998	0.000
	POW	$K = 1.008 \times K_5^{1.001}$	0.999	0.000
K_7	LIN	$K = -0.00002117 + 1.062 \times K_7$	0.993	0.000
	QUA	$K = 1.044 \times K_7 + 0.208 \times K_7^2$	0.993	0.000
	CUB	$K = -0.001 + 1.14 \times K_7 - 2.127 \times K_7^2 + 15.45 \times K_7^3$	0.993	0.000
	POW	$K = 1.062 \times K_7^{1.000}$	0.997	0.000

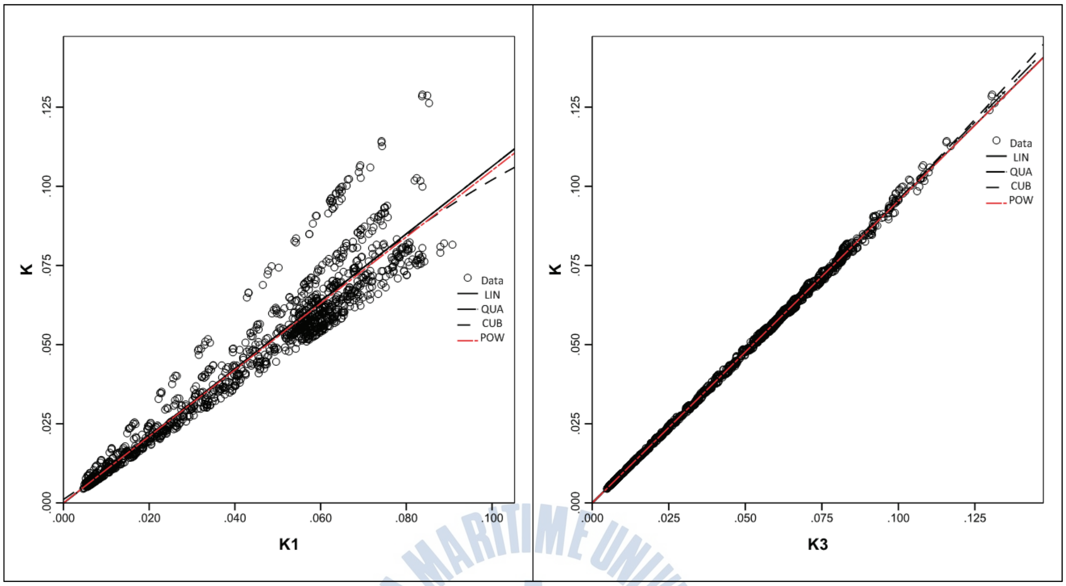


Figure 5.13 K predictive models by K_1 and K_3 in $0.12 \le K < 0.13$

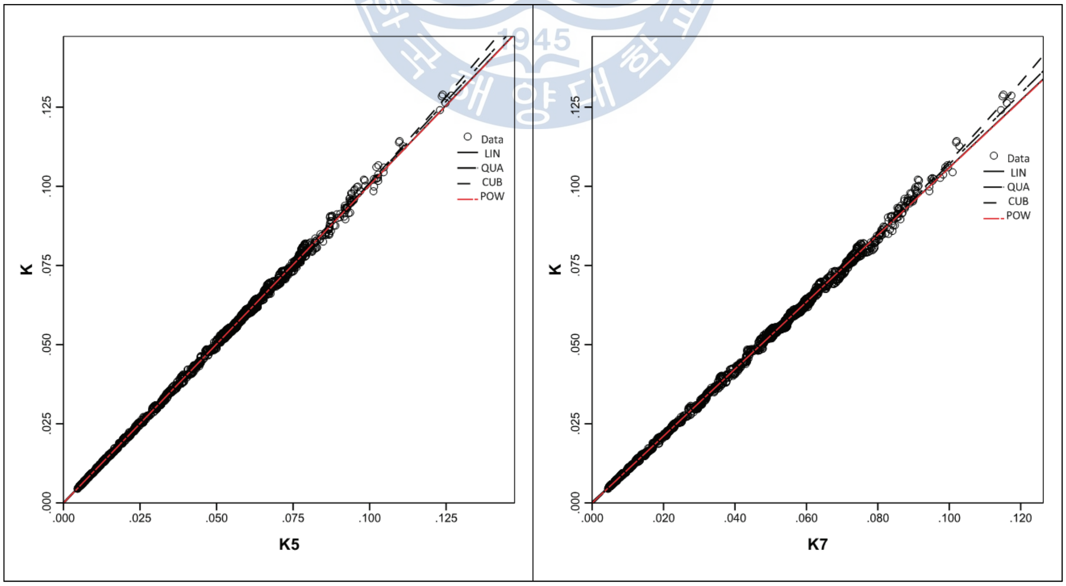


Figure 5.14 K predictive models by K_5 and K_7 in $0.12 \le K < 0.13$

Table 5.10 Regression models for predicting K in $0.13 \le K < 0.14$

Estimate	Model		R^2	F-sig.
K_1	**LIN**	$K = -0.002 + 1.116 \times K_1$	0.982	0.000
	QUA	$K = 0.004 + 0.668 \times K_1 + 5.607 \times K_1^2$	0.991	0.000
	CUB	$K = -0.004 + 1.621 \times K_1 - 20.848 \times K_1^2 + 202.911 \times K_1^3$	0.997	0.000
	POW	$K = 1.104 \times K_1^{1.011}$	0.997	0.000
K_3	**LIN**	$K = 0.965 \times K_3$	1.000	0.000
	QUA	$K = 0.948 \times K_3 + 0.176 \times K_3^2$	1.000	0.000
	CUB	$K = 0.979 \times K_3 - 0.501 \times K_3^2 + 3.908 \times K_3^3$	1.000	0.000
	POW	$K = 0.965 \times K_3^{1.001}$	1.000	0.000
K_5	**LIN**	$K = 1.018 \times K_5$	1.000	0.000
	QUA	$K = 0.998 \times K_5 + 0.217 \times K_5^2$	1.000	0.000
	CUB	$K = 1.036 \times K_5 - 0.641 \times K_5^2 + 5.23 \times K_5^3$	1.000	0.000
	POW	$K = 1.018 \times K_5^{1.001}$	1.000	0.000
K_7	**LIN**	$K = 1.077 \times K_7$	0.999	0.000
	QUA	$K = 1.043 \times K_7 + 0.391 \times K_7^2$	0.999	0.000
	CUB	$K = 1.131 \times K_7 - 1.728 \times K_7^2 + 13.847 \times K_7^3$	0.999	0.000
	POW	$K = 1.077 \times K_7^{1.001}$	1.000	0.000

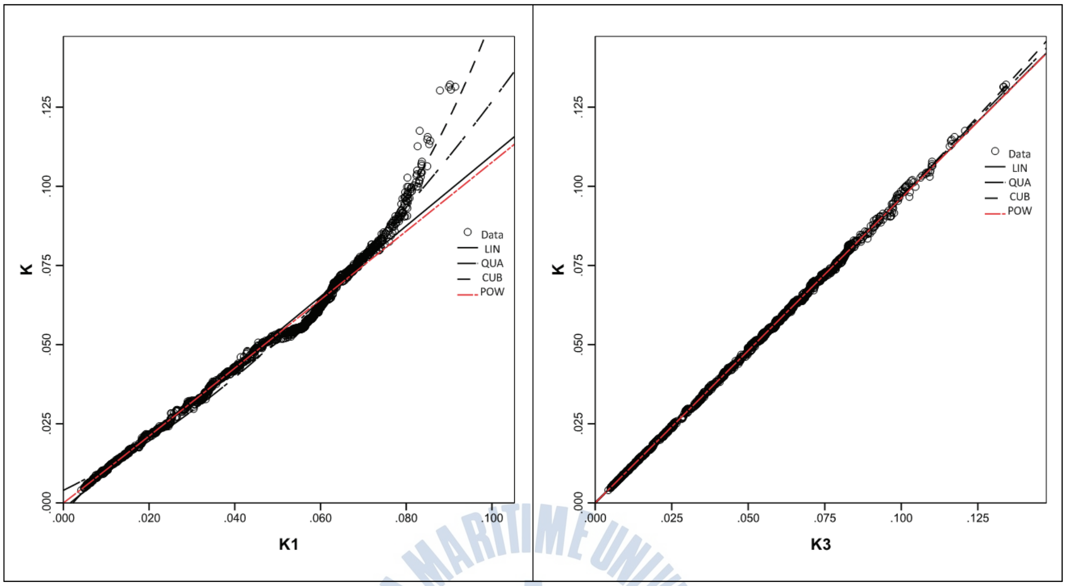


Figure 5.15 K predictive models by K_1 and K_3 in $0.13 \le K < 0.14$

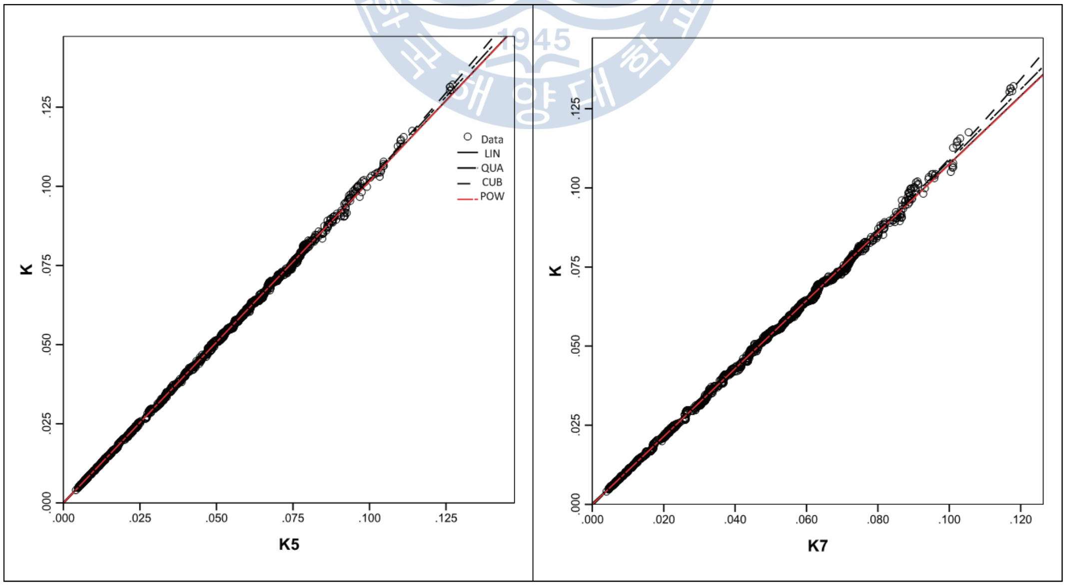


Figure 5.16 K predictive models by K_5 and K_7 in $0.13 \le K < 0.14$

Table 5.11 Regression models for predicting K in $0.14 \le K < 0.15$

Estimate	Model		R^2	F-sig.
K_1	**LIN**	$K = -0.001 + 1.108 \times K_1$	0.922	0.000
	QUA	$K = 0.003 + 0.836 \times K_1 + 3.205 \times K_1^2$	0.926	0.000
	CUB	$K = -0.003 + 1.597 \times K_1 - 17.15 \times K_1^2 + 147.651 \times K_1^3$	0.931	0.000
	POW	$K = 1.044 \times K_1^{0.992}$	0.974	0.000
K_3	**LIN**	$K = -0.0000684 + 0.976 \times K_3$	0.998	0.000
	QUA	$K = 0.00008044 + 0.968 \times K_3 + 0.077 \times K_3^2$	0.998	0.000
	CUB	$K = -0.00002391 + 0.978 \times K_3 - 0.123 \times K_3^2 + 1.041 \times K_3^3$	0.998	0.000
	POW	$K = 0.976 \times K_3^{1.000}$	0.999	0.000
K_5	**LIN**	$K = -0.00006994 + 1.009 \times K_5$	0.998	0.000
	QUA	$K = 0.00008028 + 1.001 \times K_5 + 0.083 \times K_5^2$	0.998	0.000
	CUB	$K = -0.0000297 + 1.012 \times K_5 - 0.143 \times K_5^2 + 1.212 \times K_5^3$	0.998	0.000
	POW	$K = 1.009 \times K_5^{1.000}$	0.999	0.000
K_7	**LIN**	$K = -0.00002469 + 1.083 \times K_7$	0.993	0.000
	QUA	$K = 1.071 \times K_7 + 0.13 \times K_7^2$	0.993	0.000
	CUB	$K = 1.119 \times K_7 - 0.948 \times K_7^2 + 6.309 \times K_7^3$	0.993	0.000
	POW	$K = 1.083 \times K_7^{1.000}$	0.997	0.000

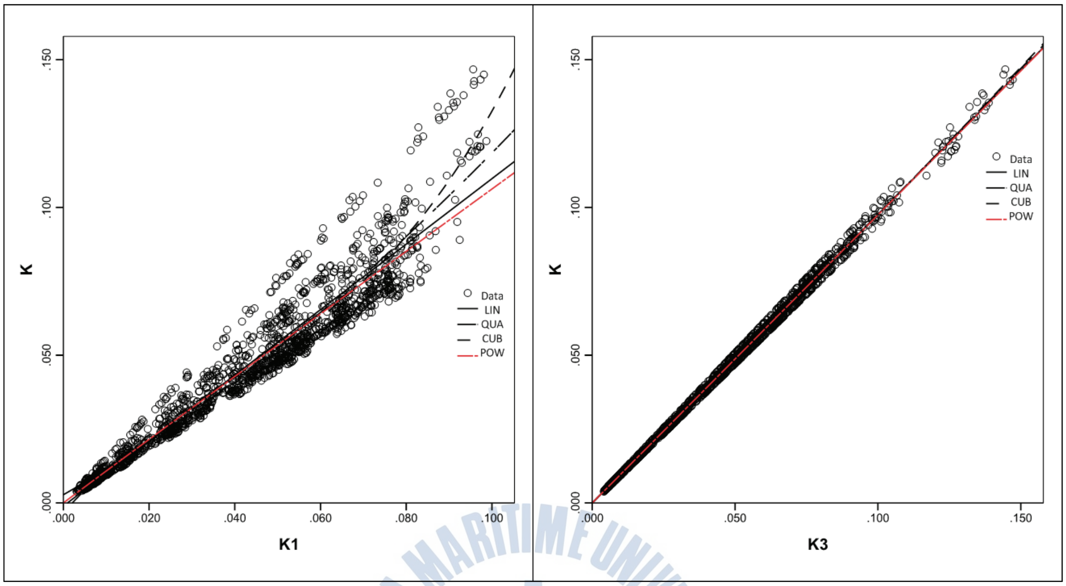


Figure 5.17 K predictive models by K_1 and K_3 in $0.14 \le K < 0.15$

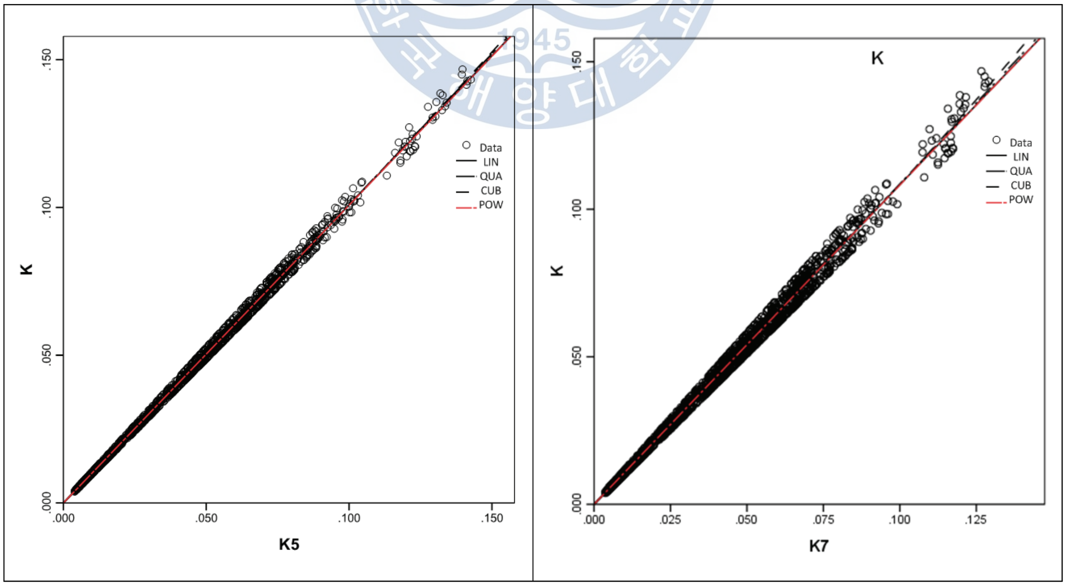


Figure 5.18 K predictive models by K_5 and K_7 in $0.14 \le K < 0.15$

As a result, K predictive models appeared to be appropriate in a higher explanatory power(R^2) by the estimates K_3, K_5, and K_7 than by the estimate K_1 for all the ranges of interval. And linear, quadratic, and cubic models appeared to be appropriate in a high explanatory power(R^2) by the estimates K_1, K_3, K_5, and K_7 for the specific range of interval, but power model appeared to be much more appropriate by the estimate K_7 than other models for the rural traffic flow characteristics as well as the urban traffic flow characteristics as summarized in **Tables 5.3~5.11** and as shown in **Figures 5.1~5.18**.

5.2 Model verification

In order to ensure the validity of the K predictive models developed, correlation analysis and t-Test for matched pairs were applied between the calculated and expected hourly volume factor(K) as follows(Lapin, 1983);

$$r = \frac{n\sum_{i=1}^{n}[(K_{cal})_i \times (K_{exp})_i] - [\sum_{i=1}^{n}(K_{cal})_i] \times [\sum_{i=1}^{n}(K_{exp})_i]}{\sqrt{n\sum_{i=1}^{n}[(K_{cal})_i]^2 - [\sum_{i=1}^{n}(K_{cal})_i]^2} \times \sqrt{n\sum_{i=1}^{n}[(K_{exp})_i]^2 - [\sum_{i=1}^{n}(K_{exp})_i]^2}} \quad (5.\ 6)$$

where, r : correlation coefficients

$(K_{cal})_i$: $i-th$ K calculated

$(K_{exp})_i$: $i-th$ K expected

n : no. of paired samples

Also, $t = \dfrac{\overline{D}}{\dfrac{s_D}{\sqrt{n}}}$ (5. 7)

$$\overline{D} = \frac{1}{n}\sum_{i=1}^{n} D_i \quad (5.\ 8)$$

$$D_i = (K_{cal})_i - (K_{exp})_i \quad (5.\ 9)$$

$$s_D = \sqrt{\frac{\sum_{i=1}^{n}(D_i - \overline{D})^2}{n-1}} \quad (5.10)$$

where, t : t statistic of matched pair samples

s_D : standard deviation of difference in K_{cal} and K_{exp}

$\overline{D}$: mean of difference in K_{cal} and K_{exp}

D_i : difference in K_{cal} and K_{exp}

Moreover, the results of correlation analysis appeared to be higher in the correlation coefficient(r) by the estimates K_3, K_5, and K_7 than in the correlation coefficient(r) by the estimate K_1, and the K predictive models by the estimates K_3, K_5, and K_7 proved to be more effective in predicting hourly volume factor(K) than the K predictive model by the estimate K_1 as summarized in **Tables 5.12~5.20**. Also the results of t-Test analysis proved to be more effective in predicting hourly volume factor(K) by the power model than the linear, quadratic and cubic ones for all the ranges of interval in the basic expressway segments as summarized in **Tables 5.21~5.29** and as shown in **Figures 5.19~5.27**.

Table 5.12 Results of correlation analysis for $0.06 \le K < 0.07$

Estimate	Correlation coefficient(r)		Estimate	Correlation coefficient(r)	
K_1	**LIN**	0.998	K_3	**LIN**	1.000
	QUA	0.999		**QUA**	1.000
	CUB	0.999		**CUB**	1.000
	POW	0.998		**POW**	1.000
K_5	**LIN**	1.000	K_7	**LIN**	1.000
	QUA	1.000		**QUA**	1.000
	CUB	1.000		**CUB**	1.000
	POW	1.000		**POW**	1.000

Table 5.13 Results of correlation analysis for $0.07 \le K < 0.08$

Estimate	Correlation coefficient(r)		Estimate	Correlation coefficient(r)	
K_1	**LIN**	0.996	K_3	**LIN**	1.000
	QUA	0.998		**QUA**	1.000
	CUB	0.999		**CUB**	1.000
	POW	0.996		**POW**	1.000
K_5	**LIN**	1.000	K_7	**LIN**	1.000
	QUA	1.000		**QUA**	1.000
	CUB	1.000		**CUB**	1.000
	POW	1.000		**POW**	1.000

Table 5.14 Results of correlation analysis for 0.08≤K<0.09

Estimate	Correlation coefficient(r)		Estimate	Correlation coefficient(r)	
K_1	**LIN**	0.999	K_3	**LIN**	1.000
	QUA	0.999		**QUA**	1.000
	CUB	0.999		**CUB**	1.000
	POW	0.999		**POW**	1.000
K_5	**LIN**	1.000	K_7	**LIN**	1.000
	QUA	1.000		**QUA**	1.000
	CUB	1.000		**CUB**	1.000
	POW	1.000		**POW**	1.000

Table 5.15 Results of correlation analysis for 0.09≤K<0.10

Estimate	Correlation coefficient(r)		Estimate	Correlation coefficient(r)	
K_1	**LIN**	0.996	K_3	**LIN**	1.000
	QUA	0.997		**QUA**	1.000
	CUB	0.998		**CUB**	1.000
	POW	0.996		**POW**	1.000
K_5	**LIN**	1.000	K_7	**LIN**	1.000
	QUA	1.000		**QUA**	1.000
	CUB	1.000		**CUB**	1.000
	POW	1.000		**POW**	1.000

Table 5.16 Results of correlation analysis for 0.10≤K<0.11

Estimate	Correlation coefficient(r)		Estimate	Correlation coefficient(r)	
K_1	**LIN**	0.997	K_3	**LIN**	1.000
	QUA	0.998		**QUA**	1.000
	CUB	0.999		**CUB**	1.000
	POW	0.997		**POW**	1.000
K_5	**LIN**	1.000	K_7	**LIN**	1.000
	QUA	1.000		**QUA**	1.000
	CUB	1.000		**CUB**	1.000
	POW	1.000		**POW**	1.000

Table 5.17 Results of correlation analysis for 0.11≤K<0.12

Estimate	Correlation coefficient(r)		Estimate	Correlation coefficient(r)	
K_1	**LIN**	0.992	K_3	**LIN**	1.000
	QUA	0.996		**QUA**	1.000
	CUB	0.998		**CUB**	1.000
	POW	0.992		**POW**	1.000
K_5	**LIN**	1.000	K_7	**LIN**	0.999
	QUA	1.000		**QUA**	0.999
	CUB	1.000		**CUB**	0.999
	POW	1.000		**POW**	0.999

Table 5.18 Results of correlation analysis for $0.12 \leq K < 0.13$

Estimate	Correlation coefficient(r)		Estimate	Correlation coefficient(r)	
K_1	**LIN**	0.991	K_3	**LIN**	1.000
	QUA	0.995		**QUA**	1.000
	CUB	0.998		**CUB**	1.000
	POW	0.991		**POW**	1.000
K_5	**LIN**	1.000	K_7	**LIN**	1.000
	QUA	1.000		**QUA**	1.000
	CUB	1.000		**CUB**	1.000
	POW	1.000		**POW**	1.000

Table 5.19 Results of correlation analysis for $0.13 \leq K < 0.14$

Estimate	Correlation coefficient(r)		Estimate	Correlation coefficient(r)	
K_1	**LIN**	0.991	K_3	**LIN**	1.000
	QUA	0.996		**QUA**	1.000
	CUB	0.999		**CUB**	1.000
	POW	0.991		**POW**	1.000
K_5	**LIN**	1.000	K_7	**LIN**	1.000
	QUA	1.000		**QUA**	1.000
	CUB	1.000		**CUB**	1.000
	POW	1.000		**POW**	1.000

Table 5.20 Results of correlation analysis for $0.14 \leq K < 0.15$

Estimate	Correlation coefficient(r)		Estimate	Correlation coefficient(r)	
K_1	**LIN**	0.991	K_3	**LIN**	1.000
	QUA	0.994		**QUA**	1.000
	CUB	0.996		**CUB**	1.000
	POW	0.991		**POW**	1.000
K_5	**LIN**	1.000	K_7	**LIN**	1.000
	QUA	1.000		**QUA**	1.000
	CUB	1.000		**CUB**	1.000
	POW	1.000		**POW**	1.000

Table 5.21 t-Test results between K_{cal} and K_{exp} for $0.06 \leq K < 0.07$

Estimate		t-value	p-value	Result	Estimate		t-value	p-value	Result
K_1	**LIN**	0.474	0.636	Accept	K_3	**LIN**	11.680	0.000	Reject
	QUA	0.494	0.621	Accept		**QUA**	11.535	0.000	Reject
	CUB	0.472	0.637	Accept		**CUB**	5.769	0.000	Reject
	POW	0.793	0.428	Accept		**POW**	11.840	0.000	Reject
K_5	**LIN**	5.138	0.000	Reject	K_7	**LIN**	1.162	0.246	Accept
	QUA	5.221	0.000	Reject		**QUA**	1.304	0.193	Accept
	CUB	0.040	0.968	Accept		**CUB**	-3.055	0.002	Reject
	POW	4.883	0.000	Reject		**POW**	1.761	0.079	Accept

Table 5.22 t-Test results between K_{cal} and K_{exp} for $0.07 \leq K < 0.08$

Estimate		t-value	p-value	Result	Estimate		t-value	p-value	Result
K_1	LIN	-0.645	0.514	Accept	K_3	LIN	-2.375	0.018	Reject
	QUA	-3.137	0.002	Reject		QUA	10.092	0.000	Reject
	CUB	-9.278	0.000	Reject		CUB	21.572	0.000	Reject
	POW	0.283	0.778	Accept		POW	-1.547	0.123	Accept
K_5	LIN	-2.207	0.028	Accept	K_7	LIN	-0.671	0.503	Accept
	QUA	9.171	0.000	Reject		QUA	9.177	0.000	Reject
	CUB	12.926	0.000	Reject		CUB	-3.341	0.001	Reject
	POW	-2.162	0.031	Accept		POW	-0.235	0.814	Accept

Table 5.23 t-Test results between K_{cal} and K_{exp} for $0.08 \leq K < 0.09$

Estimate		t-value	p-value	Result	Estimate		t-value	p-value	Result
K_1	LIN	-4.592	0.000	Reject	K_3	LIN	-0.106	0.916	Accept
	QUA	-0.511	0.610	Accept		QUA	-1.118	0.264	Accept
	CUB	42.735	0.000	Reject		CUB	-0.624	0.533	Accept
	POW	0.451	0.652	Accept		POW	-0.838	0.403	Accept
K_5	LIN	-1.825	0.069	Accept	K_7	LIN	0.189	0.850	Accept
	QUA	-1.233	0.218	Accept		QUA	-1.018	0.309	Accept
	CUB	-0.694	0.488	Accept		CUB	5.370	0.000	Reject
	POW	-0.810	0.418	Accept		POW	-1.869	0.062	Accept

Table 5.24 t-Test results between K_{cal} and K_{exp} for $0.09 \leq K < 0.10$

Estimate		t-value	p-value	Result	Estimate		t-value	p-value	Result
K_1	**LIN**	3.553	0.000	Reject	K_3	**LIN**	-11.415	0.000	Reject
	QUA	5.901	0.000	Reject		**QUA**	-11.391	0.000	Reject
	CUB	6.904	0.000	Reject		**CUB**	-11.407	0.000	Reject
	POW	0.953	0.341	Accept		**POW**	-10.651	0.000	Reject
K_5	**LIN**	-16.459	0.000	Reject	K_7	**LIN**	0.684	0.495	Accept
	QUA	-15.835	0.000	Reject		**QUA**	0.609	0.543	Accept
	CUB	-16.076	0.000	Reject		**CUB**	-0.106	0.916	Accept
	POW	-15.904	0.000	Reject		**POW**	0.034	0.973	Accept

Table 5.25 t-Test results between K_{cal} and K_{exp} for $0.10 \leq K < 0.11$

Estimate		t-value	p-value	Result	Estimate		t-value	p-value	Result
K_1	**LIN**	1.933	0.054	Accept	K_3	**LIN**	8.351	0.000	Reject
	QUA	-2.474	0.014	Reject		**QUA**	8.551	0.000	Reject
	CUB	1.197	0.232	Accept		**CUB**	9.240	0.000	Reject
	POW	0.283	0.778	Accept		**POW**	8.650	0.000	Reject
K_5	**LIN**	15.675	0.000	Reject	K_7	**LIN**	0.695	0.487	Accept
	QUA	15.693	0.000	Reject		**QUA**	0.070	0.944	Accept
	CUB	16.196	0.000	Reject		**CUB**	-2.457	0.015	Reject
	POW	15.712	0.000	Reject		**POW**	-0.406	0.685	Accept

Table 5.26 t-Test results between K_{cal} and K_{exp} for $0.11 \leq K < 0.12$

Estimate		t-value	p-value	Result	Estimate		t-value	p-value	Result
K_1	LIN	-0.508	0.612	Accept	K_3	LIN	4.063	0.000	Reject
	QUA	-0.790	0.430	Accept		QUA	18.431	0.000	Reject
	CUB	-6.948	0.000	Reject		CUB	5.701	0.000	Reject
	POW	1.139	0.255	Accept		POW	9.591	0.000	Reject
K_5	LIN	-1.364	0.174	Accept	K_7	LIN	-3.462	0.001	Reject
	QUA	9.555	0.000	Reject		QUA	8.874	0.000	Reject
	CUB	-2.089	0.038	Accept		CUB	11.301	0.000	Reject
	POW	1.114	0.266	Accept		POW	0.084	0.993	Accept

Table 5.27 t-Test results between K_{cal} and K_{exp} for $0.12 \leq K < 0.13$

Estimate		t-value	p-value	Result	Estimate		t-value	p-value	Result
K_1	LIN	-0.226	0.821	Accept	K_3	LIN	-2.382	0.018	Reject
	QUA	-0.145	0.885	Accept		QUA	0.406	0.685	Accept
	CUB	0.034	0.973	Accept		CUB	-5.788	0.000	Reject
	POW	0.854	0.397	Accept		POW	-1.531	0.127	Accept
K_5	LIN	-1.389	0.166	Accept	K_7	LIN	-0.589	0.556	Accept
	QUA	1.533	0.126	Accept		QUA	1.479	0.140	Accept
	CUB	-5.326	0.000	Reject		CUB	2.875	0.004	Reject
	POW	-0.579	0.563	Accept		POW	-0.772	0.441	Accept

Table 5.28 t-Test results between K_{cal} and K_{exp} for $0.13 \leq K < 0.14$

Estimate		t-value	p-value	Result	Estimate		t-value	p-value	Result
K_1	**LIN**	1.319	0.188	Accept	K_3	**LIN**	0.344	0.731	Accept
	QUA	0.057	0.954	Accept		**QUA**	10.497	0.000	Reject
	CUB	7.345	0.000	Reject		**CUB**	-1.070	0.286	Accept
	POW	1.220	0.223	Accept		**POW**	4.391	0.000	Reject
K_5	**LIN**	3.148	0.002	Reject	K_7	**LIN**	-2.703	0.007	Reject
	QUA	12.791	0.000	Reject		**QUA**	8.950	0.000	Reject
	CUB	3.129	0.002	Reject		**CUB**	-10.123	0.000	Reject
	POW	7.248	0.000	Reject		**POW**	0.307	0.759	Accept

Table 5.29 t-Test results between K_{cal} and K_{exp} for $0.14 \leq K < 0.15$

Estimate		t-value	p-value	Result	Estimate		t-value	p-value	Result
K_1	**LIN**	-0.172	0.863	Accept	K_3	**LIN**	13.585	0.000	Reject
	QUA	-1.097	0.274	Accept		**QUA**	13.311	0.000	Reject
	CUB	-1.630	0.104	Accept		**CUB**	13.462	0.000	Reject
	POW	1.366	0.173	Accept		**POW**	11.686	0.000	Reject
K_5	**LIN**	9.103	0.000	Reject	K_7	**LIN**	-0.025	0.980	Accept
	QUA	8.472	0.000	Reject		**QUA**	1.372	0.171	Accept
	CUB	8.512	0.000	Reject		**CUB**	-2.552	0.011	Reject
	POW	7.266	0.000	Reject		**POW**	-0.248	0.804	Accept

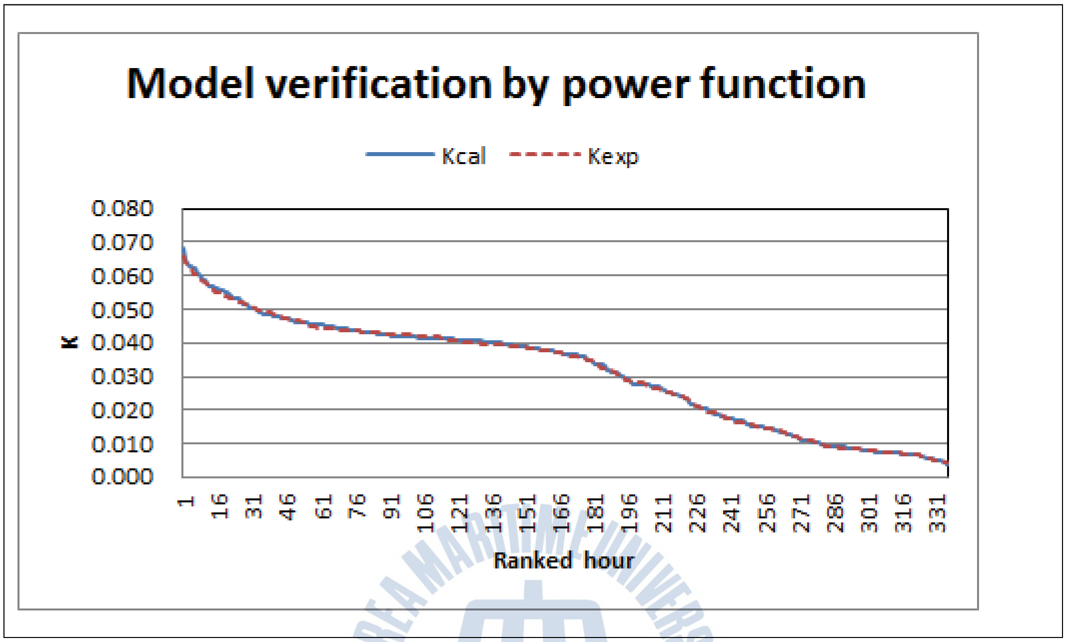


Figure 5.19 Model verification for 0.06≤K<0.07 in expressways

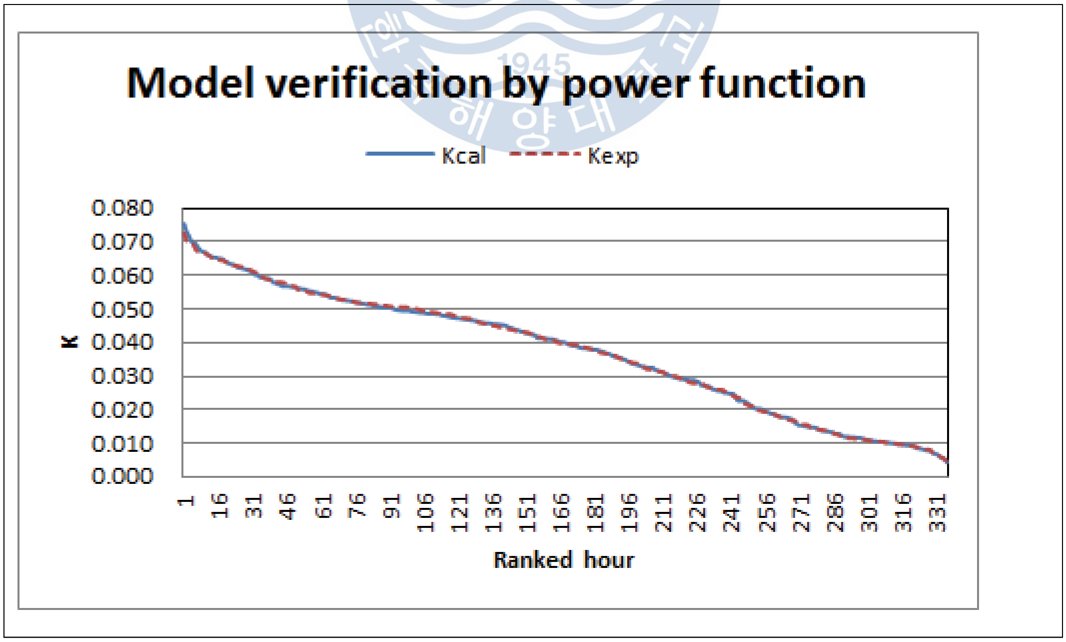


Figure 5.20 Model verification for 0.07≤K<0.08 in expressways

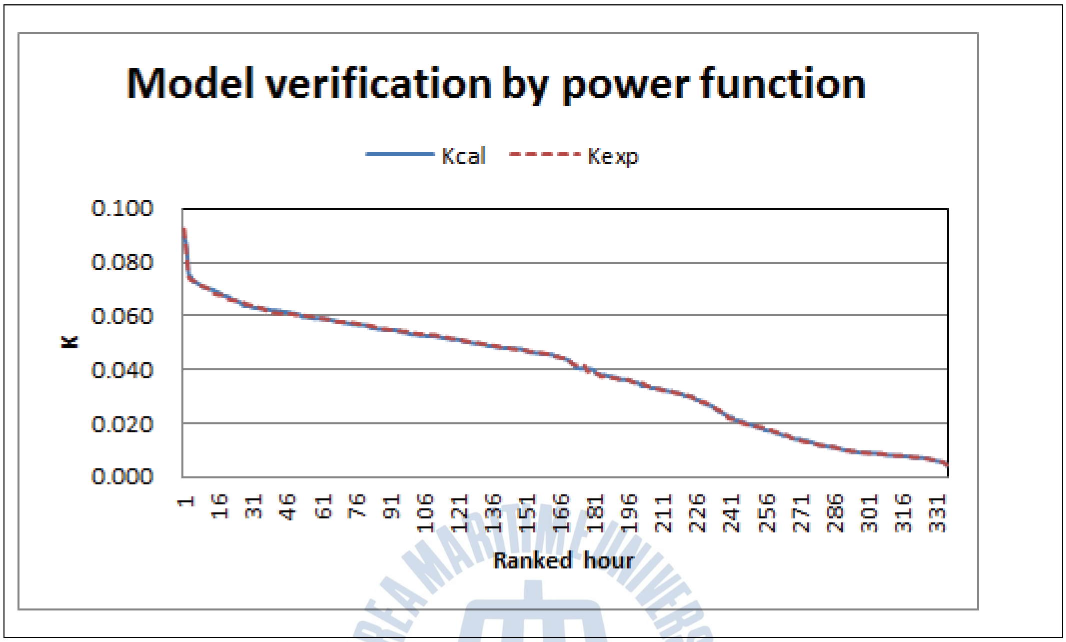


Figure 5.21 Model verification for 0.08≤K<0.09 in expressways

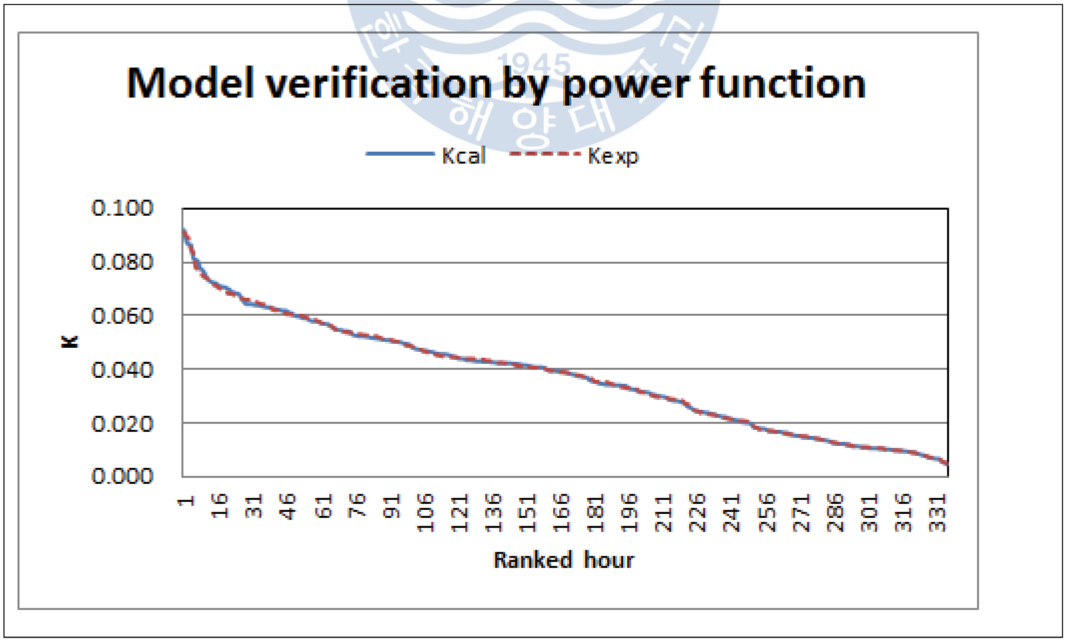


Figure 5.22 Model verification for 0.09≤K<0.10 in expressways

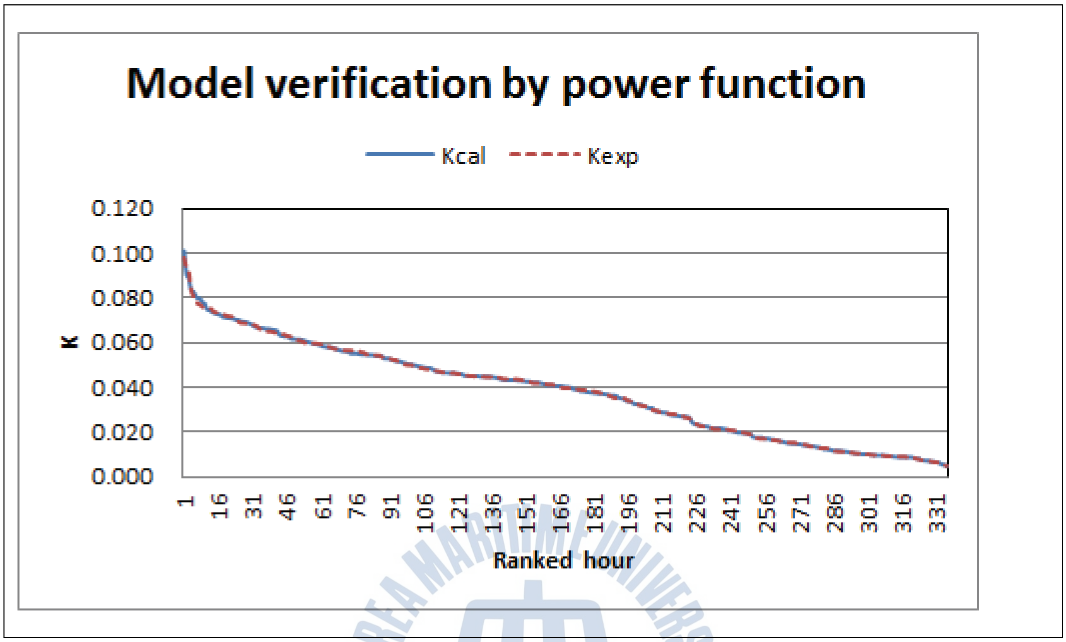


Figure 5.23 Model verification for 0.10≤K<0.11 in expressways

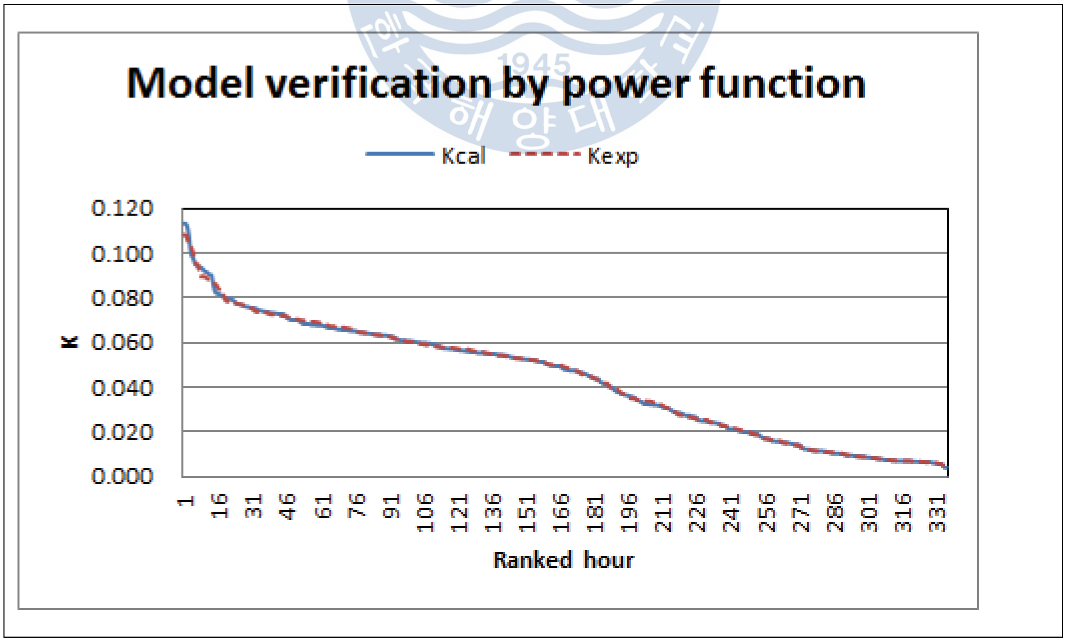


Figure 5.24 Model verification for 0.11≤K<0.12 in expressways

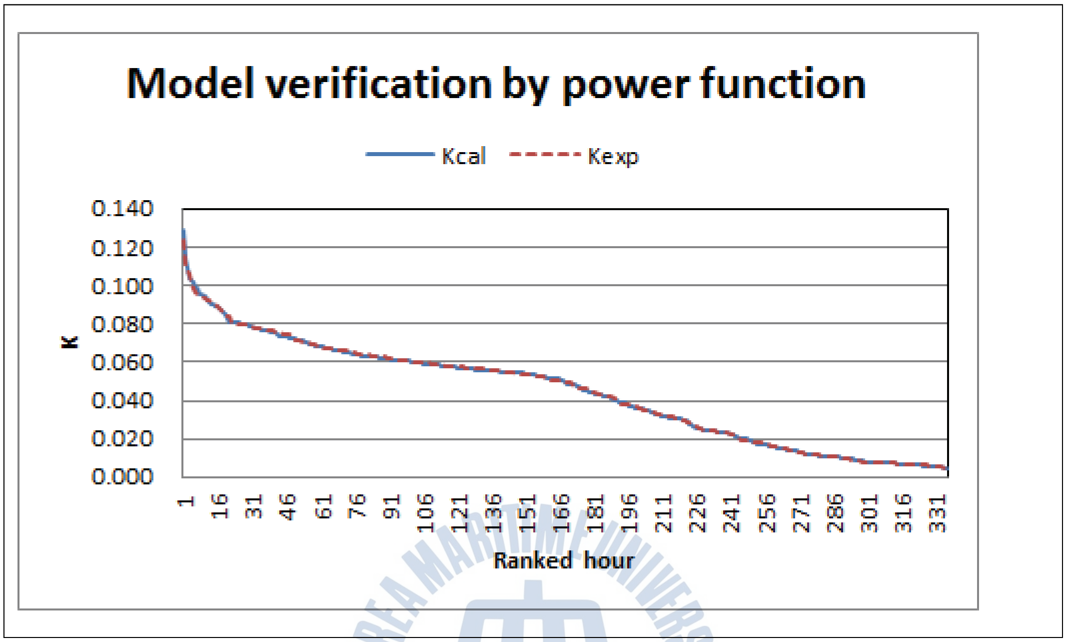


Figure 5.25 Model verification for 0.12≤K<0.13 in expressways

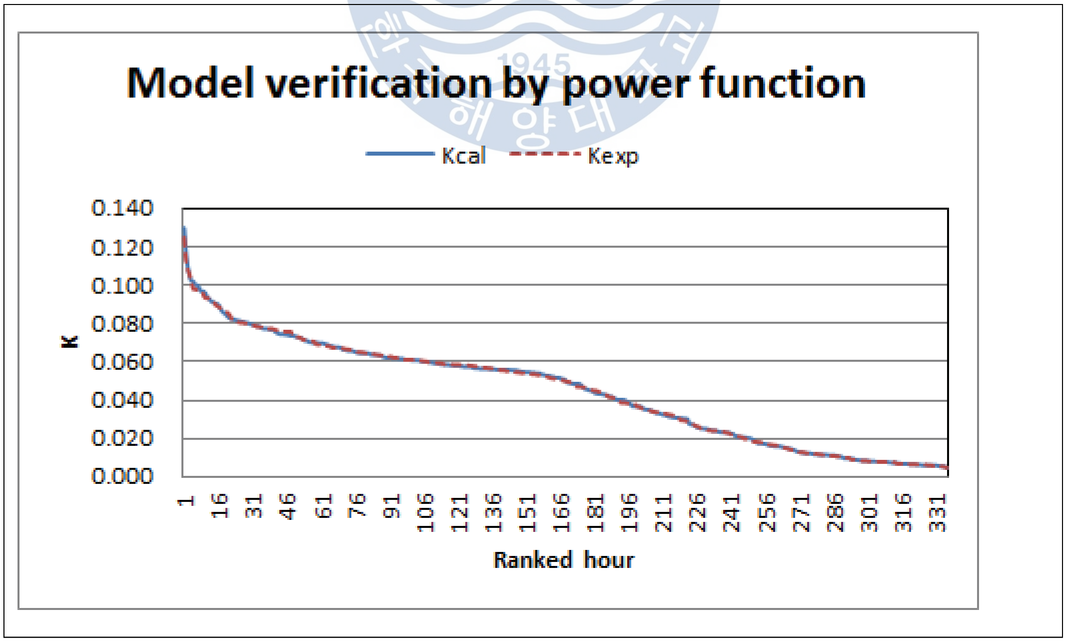


Figure 5.26 Model verification for 0.13≤K<0.14 in expressways

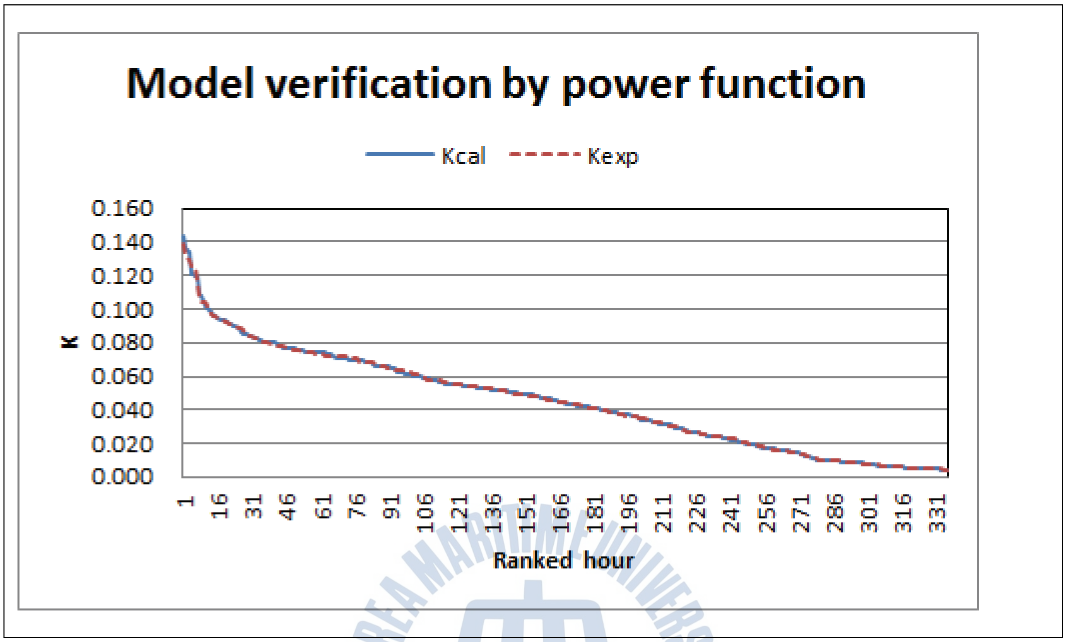


Figure 5.27 Model verification for 0.14≤K<0.15 in expressways

As a result, the estimate of hourly volume factor for a short-term period proved to be reliably used for predicting the hourly volume factor(K) in the basic expressway segments, and especially power model on the basis of the estimate K_7 for a week proved to be more appropriate in predicting the hourly volume factor(K) with a high explanatory power and validity in expressways showing the rural traffic flow characteristics(K≥0.12) as well as the urban traffic flow characteristics(K < 0.12).

6. Conclusions and Suggestions

From the traffic characteristic analyses, the analyses of hourly volume factor(K) and estimate K_j, and the development and verification of model in the basic expressway segments, the following conclusions were drawn;

ⅰ) Traffic characteristics appeared to show a considerable difference in the direction of the basic expressway segments. So, it was needed to establish the expressway traffic management system based on the directional traffic characteristics for improving the efficiency of expressway.

ⅱ) Hourly volume factor(K) in the direction of expressways appeared to have a highly positive correlation with estimate K_j(j=1, 3, 5, 7) for a short-term period. So, it was needed to examine the relationship between hourly volume factor(K) and the estimate K_j for each direction of the expressways.

ⅲ) The highest hourly proportions of K calculated in expressways appeared to show the rural and urban traffic flow characteristics. So, it was needed to classify these hourly proportions of K for in-depth analysis into; $0.06 \leq K < 0.07$, $0.07 \leq K < 0.08$, $0.08 \leq K < 0.09$, $0.09 \leq K < 0.10$, $0.10 \leq K < 0.11$, $0.11 \leq K < 0.12$, $0.12 \leq K < 0.13$, $0.13 \leq K < 0.14$, and $0.14 \leq K < 0.15$.

ⅳ) Linear, quadratic, cubic and power models appeared to have a highly correlation coefficient(r) between hourly volume factor(K) and estimate K_j(j=1, 3, 5, 7) for each range of interval. So, it was needed to select the proper model in predicting the hourly volume factor(K) with a high explanatory power(R^2).

ⅴ) Power model appeared to be very appropriate in predicting the hourly volume factor(K) by estimate K_7 with a high explanatory power(R^2) and validity for all ranges of interval. So, it was needed to verify the power model between the hourly volume factor(K) and estimate K_7 for a short-term period.

ⅵ) Model verification results appeared to show the high correlation coefficients(r) in the power model with estimate K_7 and fall inside Accept region for all ranges of interval. So, it was needed to determine the power model as the most appropriate one for predicting K in expressways showing the rural and urban traffic flow characteristics.

It was concluded that this study was needed to be continued under the various geometric characteristics of expressways for the purpose of the reliability of the hourly volume factor(K) predictive model.

References

Baek, S. K., Kim, B. J., Lee, J. H., and Son, Y. T.(2007), Design Hourly Factor Estimation with Vehicle Detection System, Journal of the Korean Society of Transportation, Vol. 25, No. 6, pp. 79-88.

Ha, J. A. and Kim. S. H.(2008), Estimating Design Hour Factor Using Permanent Survey, Journal of the Korean Society of Civil Engineers, Vol. 28, No. 2D, pp. 155-162.

Jang, T. J., Kim, J. H., Lee, E. J., and Kim, T. G.(2003), Delay Predictive Modeling on the Diverge Sections of Urban Freeway Interchange based on Real-Time Traffic Characteristics, Journal of the Korean Society of Civil Engineers, Vol. 23, No. 4D, pp. 429~437.

Jin, J. K.(2010), Derivation of the Inflection Points for Estimating the K-Factors on Highway Sections, Graduate School, Hanyang University.

Kang, S. W.(2011), A Study on Estimation of Design Hour Factor on Urban Expressways, Graduate School, Chonnam National University,

Kim, J. H.(2000), Construction of Delay predictive Models on Freeway Ramp Junctions, Graduate School, Korea Maritime University.

Kim, J. H., Ahn, H. C., Lee, E. J., and Kim, T. J.(2005), Speed predictive Modeling on the Consecutive Exit-Entrance Ramp Junctions of the Trumpet A-type Interchange, Journal of the Korean Society of Civil Engineers, Vol. 25, No. 1D, pp. 35~42.

Kim, T. G., Jung, Y. H., Park, J. M., and Ji, S. K.(2008), Capacity Analysis in the Ramp Junction of the Urban Freeway Connected with the Busan Port, Journal of the Korean Society of Civil Engineers, Vol. 28, No. 2D, pp.

205~216.

Kim, T. G., Jung, Y. N., and Fady, M. H.(2010), Delay Predicting Modeling of Urban freeway Using lane-based Characteristics, Journal of the Korean Society of Civil Engineers, Vol. 30, No. 5D, pp. 467~476.

Kim, T. G. and Jung, Y. W.(2012), Prediction of Speed in Urban Freeway Having More Freight vehicles -Based on I-696 in Michigan, International Journal of Navigation and Port Research, Vol. 36, No. 7, pp. 591~597.

Kim, T. G., Kim, S. G., Shin, K. S., and Kwon, I. Y.(2007), Speed Predictive Modeling in the Merge Influence Area of the Urban Freeway, Journal of the Korean Society of Civil Engineers, Vol. 27, No. 1D, pp. 35~42.

Kim, T, G., Kwon, M. H., and Ji, S. G.(2010), Predicting Average Speed within the Entrance and Exit Ramp Junction Areas of Urban Freeway, Journal of the Korean Society of Civil Engineers, Vol. 30, No. 3D, pp. 215~222.

Kim, T. G., Moon, B. K., Jo, I. K., and Jung, Y. N.(2009), LOS Evaluation of Urban Freeway by the Occupancy Characteristics, Journal of the Korean Society of Civil Engineers, Vol. 29, No. 3D, pp.335-345.

Kim, T. G., Moon, B. K., Lee, J. C., and Fady, M. H.(2007), Speed Correlation Models Within the Merge Influence Area of Urban Freeway Using the Lane-based Speed Characteristics, Journal of the Korean Society of Civil Engineers, Vol. 27, No. 4D, pp. 413~421.

Kim, T. G., Pyo, J. J., Kwon, M. H., and Jo, I. K.(2008), Density predictive Model within the On-ramp Merge Influence Areas of Urban Freeway, Journal of the Korean Society of Civil Engineers, Vol. 28, No. 3D, pp. 287~293.

Kim, T. G., Shin, K. S., Kim, S. G., and Kim, J. S.(2006), The Linear Density Predictive Models on the On-Ramp Junction in the Urban Freeway, Journal of the Korean Society of Civil Engineers, Vol. 26, No. 1D, pp. 59~66.

Kwon, S. B., Kim, J. H., Lee, J. Y., and Kim, T. G.(2005), Evaluation of the Speed Conversion factors within the ramp Influence Areas on Urban Freeway in Busan Area, Journal of the Korean Society of Civil Engineers, Vol. 25, No. 1D, pp. 31~38.

MLTM(2005), Road Design Standards, pp. 378-379.

MLTM(2009), Rules and Guidelines on Structure and Facility of Roads, pp. 505-506.

Oh, J. S. and Lim, S. M.(2007), Time series property of the 30th Design Hourly Factors in National Highways, Journal of Korean Society of Road Engineers, Vol. 9, No. 4, pp. 1-9.

Park, Y. J., Ahn, H. C., Kwon, I. Y., and Kim, T. G.(2004), Speed Conversion Models Within the Ramp Junctions of the Urban Freeway, Journal of the Korean Society of Civil Engineers, Vol. 24, No. 4D, pp. 549~554.

Won, C. Y.(2008), Development of An Expressway Design Hour Service Goal Factor Based on Annual Traffic Variation, Graduate School, Ajou University.

AASHTO(2001), A Policy On Geometric Design of Highways and Streets, American Association of State Highway and Transportation Officials, Washington, D.C. 20001.

Crownover, D. R.(2006), Use of Short-term interval counts to determine K Factors, Oregon Department of Transportation, August.

Garber, N. J. and Hoel, L. A.(1988), Traffic & Highway Engineering, WEST PUBLISHING COMPANY, St. Paul, MN 55164-1003.

Gerlough, D. L. and Huber, M. J.(1975), "Traffic Flow Theory", A Monograph, Special Report 165, Transportation Research Board, National Research Council, Washington, D.C.

Kim, T. G., Kim, J. H., Lee, E. J., and Kwon, I. Y.(2003), Delay Predictive Modeling on the Continuous Exit-After-Entrance Ramp Junctions of the Urban Freeway under the Speed Surveillance, Proceedings of the 4th International Symposium on Uncertainty Modeling and Analysis, ISUMA2003, 1-3 September, pp. 360~366.

Kim, Y. H. and Hall, F. L.(2004), Relationships Between Occupancy and Density Reflecting Average Vehicle Lengths, Journal of the Transportation Research Board, TRB of the national Academies, Vol. 1883, pp. 85~93.

Homburger, W. S. and Kell, J. H.(1989), Fundamentals of Traffic Engineering, 12th ed., Course Notes, Institute of Transportation Studies, University of California at Berkeley, October.

Khisty, C. J.(1990), Transportation Engineering An Introduction, Illinois Institute of Technology, Prentice Hall, Englewood Cliffs, New Jersey 07632.

Lapin, L. L.(1983), Probability and Statistics for Modern Engineering, PWS Publishers, Belmont, California 94002.

McShane, W. R., Roess, R. P., and Prassas, E. S.(1998), Traffic Engineering, 2nd ed., Prentice Hall, Upper Saddle River, New Jersey 07458.

May, A. D.(1990), Traffic Flow Fundamentals, Prentice-Hall, Englewood Cliffs, New Jersey 07632.

Sharma, S. C., Wu, Y., and Rizak, S. N.(1995), Determination of DDHV From Directional Traffic Flow, Journal of Transportation Engineering, 121(4), pp. 369~375.

Thompson, N.(1997), Ramp Up The Volume, Its International.

TRB(1975), Traffic Flow Theory, Special Report 165, Transportation Research

Board, Washington, D.C. 20001.

TRB(1997), Traffic Flow Theory, Revised Edition, Special Report 165, Transportation Research Board, Washington, D.C. 20001.

TRB(2000), Highway Capacity Manual, Transportation Research Board, Washington, D.C. 20001.

Walker, W. P.(2004), Trends Of Factors Used In Determining The 30th Highest Hourly Traffic Volumes, Federal Highway Administration, Vol. 29, No. 9, pp. 216~220.

Wright, P. H. and Paquette, R. J.(1987), Highway Engineering, 5th ed., Georgia Institute of Technology, John Wiley & Sons, Inc.