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Peak Hour Factor Analysis for Dumlupınar Boulevard in Ankara Province

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Abstract: The flow of traffic has constantly changing during any time interval of hour, day, week, month, season or year over a highway section. The Peak Hour Factor (PHF), which is a very important measure of these changes for transportation operations and designs. It shows how much the traffic flow differs from each other period of time, reveals the regularity and stability of the flow, and shows the pattern of usage or demand to link or longest section. In this study, PHF values of Dumlupınar Boulevard in Ankara, Türkiye are gathered and analyzed for different time periods by using the longest uninterrupted traffic measures and records in 2018 for Dumlupınar Boulevard which is the one of main arterials in Capital Ankara. The distribution of traffic in different time periods, the relationship between peak hour factors in different directions and the relationships between peak hour factor values calculated with respect to 05 and 15 minute intervals are analyzed and modeled. The results are evaluated for future transportation processes and management.

Keywords: Traffic stream characteristics, modeling, peak hour factor, traffic data processing, regression analysis

1. Introduction

Congestion and traffic jams may occur at many spots or sections of highways at various times. There are also many reasons for these situations, such as the increase in population and its growth rate, rapid and unplanned urbanization, vehicle ownership, single vehicle uses, inadequacy and inefficiency of facilities or infrastructure, networks, links, implementation of the plan and policies etc. Both capacity-level of service and congestion analyses require detailed motor vehicle traffic data which are gathered with only traffic counts or measures.

In Türkiye, Capital Ankara uses Urban Security Management System (KGYS) which is camera systems located on Ankara arterials, main intersections and city enter-exits in order to collect traffic data for management such as security, operation, maintenance, even planning, design and construction procedures or stages. Due to lack of regular, continuous and uninterrupted counts for traffic monitoring and measures, peak hour factors calculated 05 minute or 15 minute intervals in an hour, are used to estimate maximum flows on sections.

In this study, Dumlupınar Boulevard (DB) is selected and studied. DB is an important one of main arterials and connects the east and west of Ankara passing through city center, so it connects many residential areas, six university campuses, five malls, many public buildings and many business centers.

In this paper analysis and evaluations of peak hour factors estimated for 05-minute and 15-minute base are presented for DB in detailed manner such as month, weekdays and weekend days basis.

2. Materials and Method

In this section, main background knowledge used in the study is summarized.

2.1 Basic Knowledge

2.1.1 Traffic Stream and Its Parameters

Traffic stream is the situation that includes all components of traffic such as pedestrians, drivers, vehicles, roads, signs, environmental effects and arises as a result of the interaction of these components with each other. A change that may occur in any of these components, which are basically for transportation purposes, can also affect the traffic stream. Traffic stream parameters are divided into two categories as macroscopic parametersand microscopic parameters. Macroscopic parameters of traffic stream are flow, velocity, and density. The microscopic parameters of the traffic stream are time headway and space headway.

2.1.2 Volume and Capacity

Traffic volume is the number of vehicles passing through a particular road segment during the counted period. The counting time for the number of vehicles passing through the road section under observation may vary depending on the purpose of use of the data. Capacity is the maximum volume that can occur at a point or a particular part of a highway section in a time period or the maximum number of users that can pass there.

2.1.3 Peak Hour Factor

Peak Hour Factor is the traffic data derived to reveal whether the traffic distribution during the day is regular or not. Traffic volume and flow are variable across all road networks. Traffic density increases and decreases at certain times of the day. The main purpose of the Peak Hour Factor calculation is to reveal the degree of irregularity of the traffic volume in the peak periods for the specified time periods.

The number of users on a roadway is constantly changing throughout the day. Especially in city centers, busy time segments usually occur in the morning and evening. Transport operators and designers often deal with busy times. The design volumes are found by revealing different coefficients for the radial routes and circumferential routes between the rush hour traffic volume obtained with PHF and the annual traffic volumes. PHF analysis is the basis of these calculations made to meet the demand correctly.

PHF plays a crucial role in many situations also, such as long-term traffic forecasts, determining the time when these operations will be carried out for maintenance-repair operations, in addition to being used in traffic forecasts and modeling in situations where traffic measurement cannot be made every day of the year. If a highway requires traffic improvement, the design that meets the traffic value determined with PHF in the new design is the proper design. In addition, the PHF has one of the main roles in intersection design and traffic lights and traffic signals design.

The peak hour factor determines 05 or 15 minute time periods. PHF5 is the ratio of the traffic volume during the rush hour, to the data obtained by multiplying the traffic volume in the 05 minute period with the peak traffic by 12:

$$\text{PHF}\ (5) = \frac{Total\ \ traffic\ \ volume\ \ during\ \ the\ 1\ hour\ period\ \ when\ peak\ \ traffic\ \ (\frac{vehicle}{hour})}{12 * traffic\ \ volume\ \ during\ \ the\ 5\ miniute\ \ time\ \ period\ \ when\ peak\ \ traffic\ \ (\frac{veh.}{5\ min})} \qquad (1)$$

PHF_{15} is the ratio of the traffic volume during the rush hour, to the data obtained by multiplying the traffic volume in the 15 minute period with the peak traffic by 4:

$$\text{PHF}\ (15) = \frac{Total\ \ traffic\ \ volume\ \ during\ \ the\ 1\ hour\ period\ \ when\ peak\ \ traffic\ \ (\frac{vehicle}{hour})}{4 * traffic\ \ volume\ \ during\ \ the\ 15\ miniute\ \ time\ \ period\ \ when\ peak\ \ traffic\ \ (\frac{veh.}{15\ min})} \qquad (2)$$

The peak hour factor expresses the deviation by comparing the number of vehicles in a 1 hour time period with the maximum number of vehicles in a 05 or 15 minute time period. The maximum value of the peak hour factor is 1. The closer the peak hour factor value is to 1, the more stable the traffic distribution during that hour.

2.2 Row Data and Data Processing

In the study, between 02 January 2018 - 00:03 and 04 December 2018 - 23:58, a total of 121951 vehicle passage information just on Tuesday and Thursdays was recorded in the database recorded for each lane through the KGYS cameras on Dumlupınar Boulevard. The data obtained from the KGYS records contains the date, direction, lane number and vehicle speed readings of each vehicle in raw form.

The raw data are classified with respect to drive directions and used lanes. DB is a divided highway having three lanes in direction-1 and five lanes in other, direction-2 or eight lanes in total. The classifications include different time periods as well as directions and lanes of vehicular movements. There are 14 different time periods (TP) concerned in the calculations. Time periods 1 to 12 represent the months of the year as TP-1: January to TP-12 December respectively. In addition, TP-13 represents weekdays and TP-14 represents weekends.

A new database is generated accordingly having 05 and 15 minute intervals of successive hours, days and months including their respective 05 and 15 minute PHF calculations. Next, interrelationships between 05 minute PHF and 15 minute PHF are analyzed and tried to be modeled by means of the regression analysis.

By examining the PHF05 - PHF15 modeling and analysis results, the changes of the peak hour factors in each direction and lane according to different time periods and their relationships are evaluated. In modelling, the “a” coefficient, “b” regression constant and R2 values of the satisfying linear regression models are estimated and evaluated for month, weekday and weekend time periods, then the results are reported briefly.

3. Results

3.1 Models for Peak Hour Factor Calculations

The PHF values calculated according to the 05 and 15 minute intervals are inevitably different. The reason of these differences depends on number of intervals in one hour and their minimum and maximum PHF values. As PHF_{05} has minimum ½, PHF_{15} has ¼ minimum values their maximum is 1.

Linear regression analysis is used to correlate the 05 and 15 minute PHF's calculated for each lane on a monthly, weekday and weekend basis. The relationship between PHF's is revealed by using the equation "y = ax+b" which is the main equation of the regression analysis. In the equation, dependent variable y corresponds to PHF_{15} and independent variable x corresponds to PHF_{05}. As a result of the modeling, the regression coefficient R^2 is found and the relationship between PHF_{05} and PHF_{15} is revealed.

3.1.1 Peak Hour Factor Models for Months

For January (Time Period-1), PHF_{05} values vary between 0,52-1,00 and PHF_{15} values vary between 0,25-1,00. In addition, the R^2 values in linear models vary between 54,45% and 100,00%. January has one of the highest relation in monthly observations.

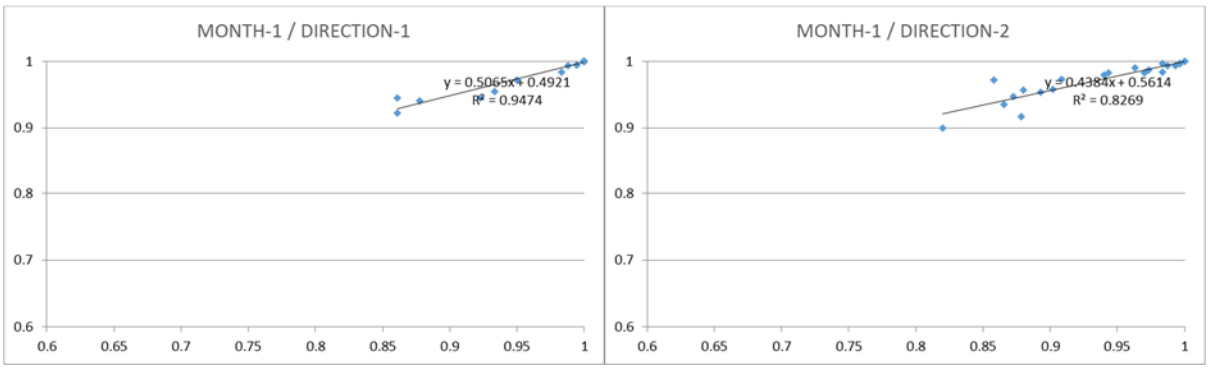

Figure-1: Time Period-1 Regression Analysis

For February (Time Period-2), PHF_{05} values vary between 0,44-0,83 and PHF_{15} values vary between 0,25-0,98. In addition, the R^2 values in linear models vary between 10,00% and 100,00%. Since the regression coefficient is low and the standard deviation is very high in February, it would be deceptive for comment.

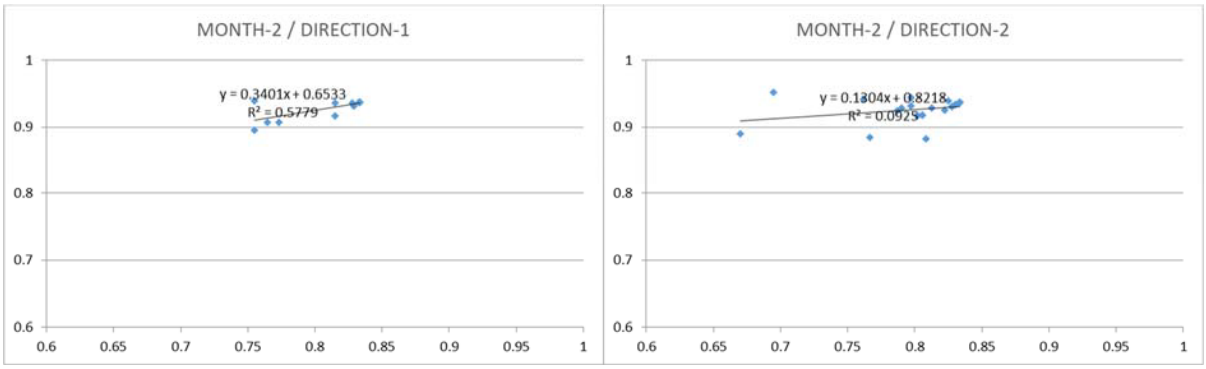

Figure-2: Time Period-2 Regression Analysis

For March (Time Period-3), PHF_{05} values vary between 0,17-1,00 and PHF_{15} values vary between 0,33-1,00. In addition, the R^2 values in linear models vary between 6,00% and 79,00%. The standard deviations of the values are very high.

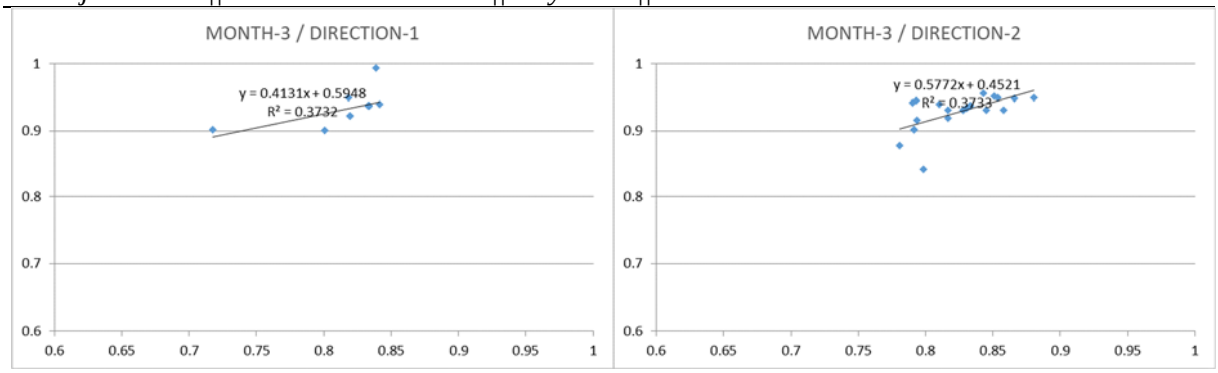

Figure-3: Time Period-3 Regression Analysis

For April (Time Period-4), PHF_{05} values vary between 0,17-1,00 and PHF_{15} values vary between 0,33-1,00. In addition, the R^2 values in linear models vary between 44,00% and 100,00%.

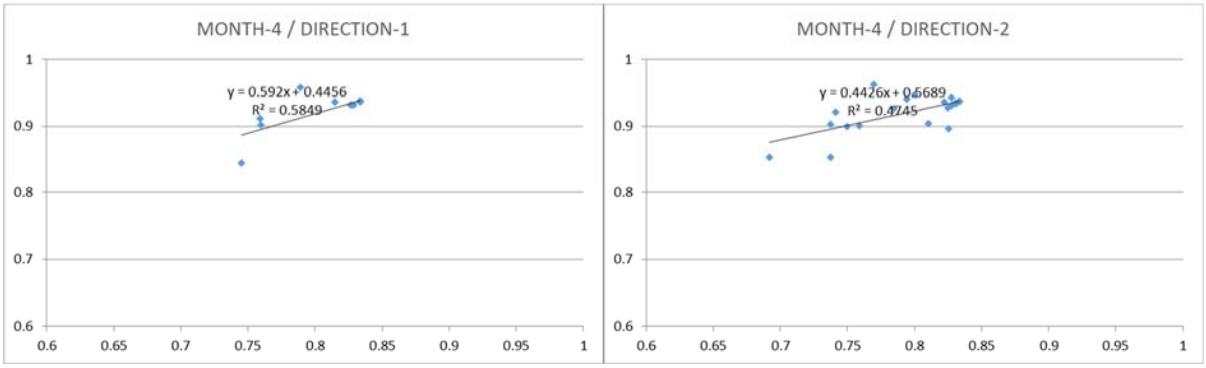

Figure-4: Time Period-4 Regression Analysis

For May (Time Period-5), PHF_{05} values vary between 0,08-1,00 and PHF_{15} values vary between 0,25-1,00. In addition, the R^2 values in linear models vary between 77,00% and 100,00%. With the high regressioncoefficient, it is concluded that the PHF assessments made for this month are correct. The only month in which the correct result is achieved is May.

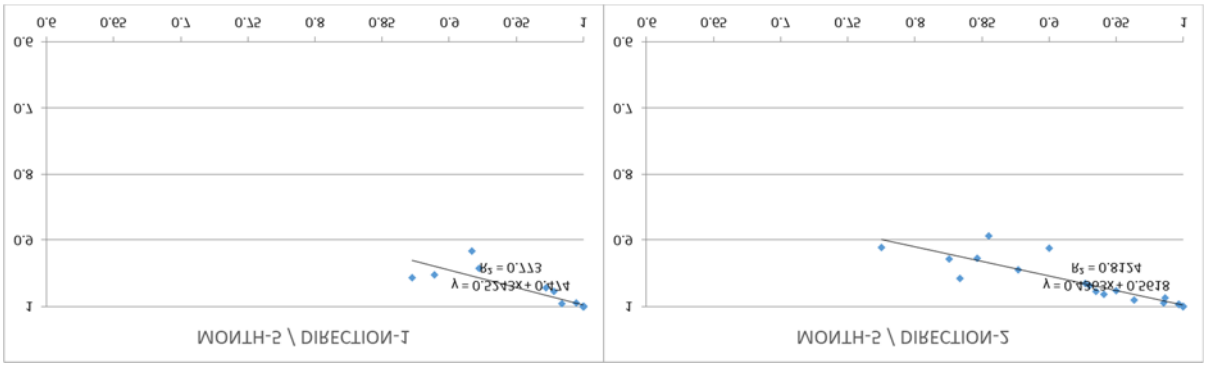

Figure-5: Time Period-5 Regression Analysis

For June (Time Period-6), PHF_{05} values vary between 0,08-0,83 and PHF_{15} values vary between 0,25-0,98. In addition, the R^2 values in linear models vary between 1,00% and 100,00%. Standard deviation is high, reliability is low for Time Period-6.

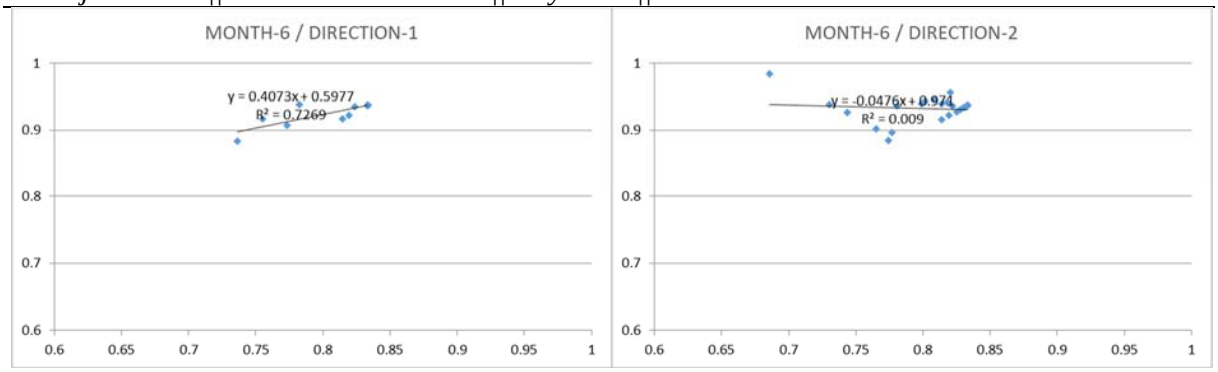

Figure-6: Time Period-6 Regression Analysis

For July (Time Period-7), PHF_{05} values vary between 0,17-0,87 and PHF_{15} values vary between 0,45-1,00. In addition, the R^2 values in linear models vary between 2,00% and 100,00%. Standard deviation is high, reliability is low for Time Period-7 also.

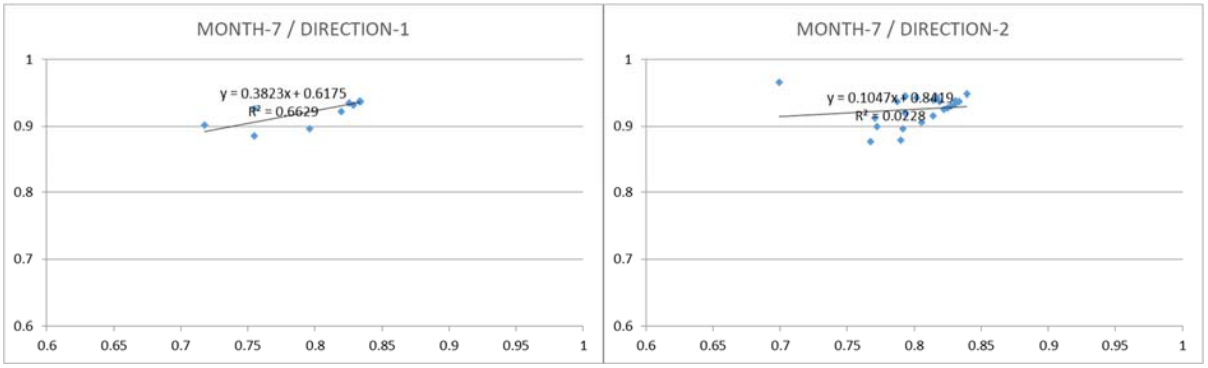

Figure-7: Time Period-7 Regression Analysis

For August (Time Period-8), PHF_{05} values vary between 0,08-0,83 and PHF_{15} values vary between 0,25-0,95. In addition, the R^2 values in linear models vary between 37,00% and 100,00%. Model is not reliable enough for this time period.

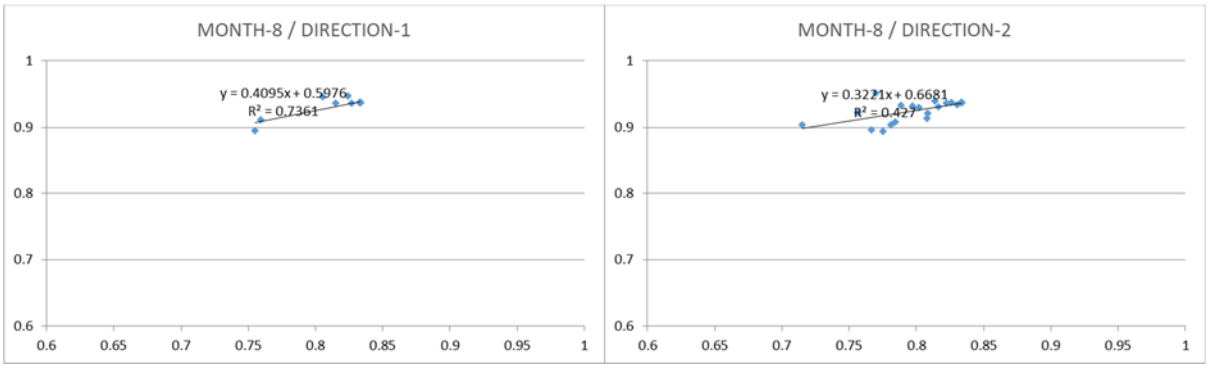

Figure-8: Time Period-8 Regression Analysis

For September (Time Period-9), PHF_{05} values vary between 0,08-1,00 and PHF_{15} values vary between 0,25- 1,00. In addition, the R^2 values in linear models vary between 1,00% and 97,00%. The standard deviation is very high in both PHF and regression analysis.

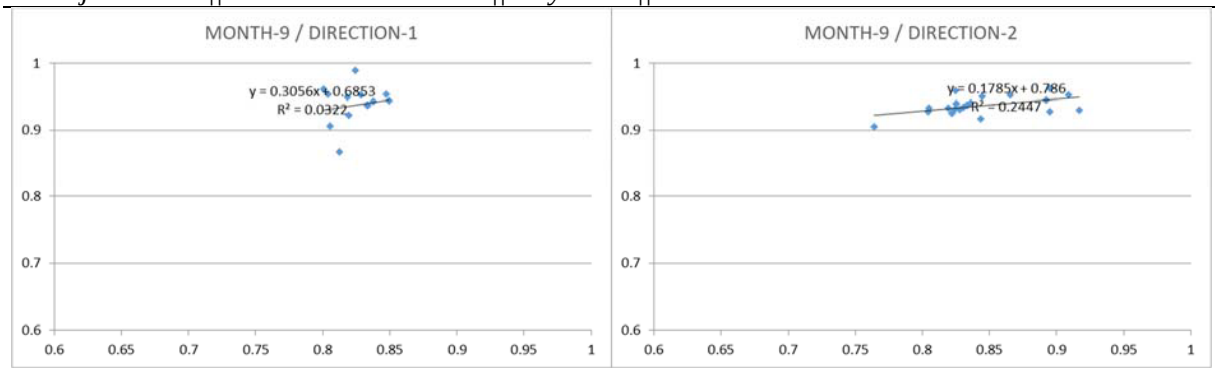

Figure-9: Time Period-9 Regression Analysis

For October (Time Period-10), PHF_{05} values vary between 0,08-1,00 and PHF_{15} values vary between 0,25-1,00. In addition, the R^2 values in linear models vary between 34,00% and 78,00%. The model is not reliable.

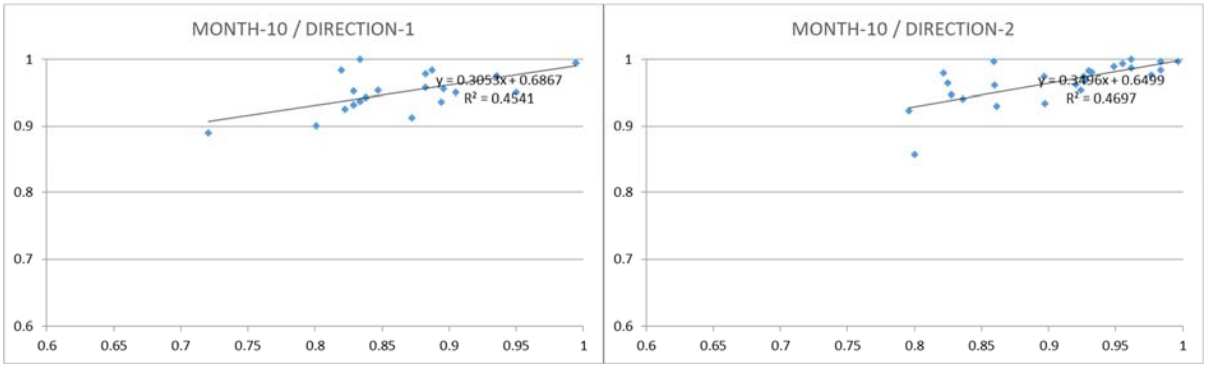

Figure-10: Time Period-10 Regression Analysis

For November (Time Period-11), PHF_{05} values vary between 0,08-1,00 and PHF_{15} values vary between 0,25- 1,00. In addition, the R^2 values in linear models vary between 6,00% and 94,00%. Model is not reliable for this time period neither.

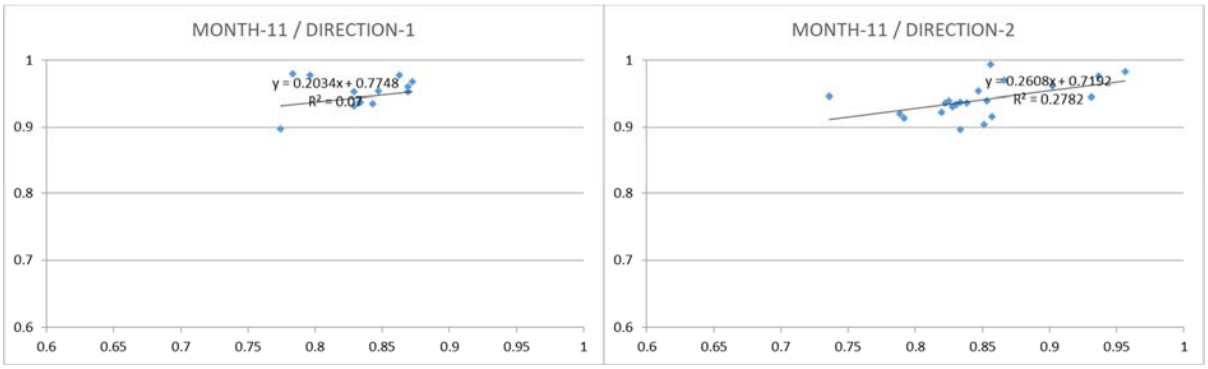

Figure-11: Time Period-11 Regression Analysis

For December (Time Period-12), PHF_{05} values vary between 0,08-0,83 and PHF_{15} values vary between 0,25- 0,98. In addition, the R^2 values in linear models vary between 60,00% and 98,00%.

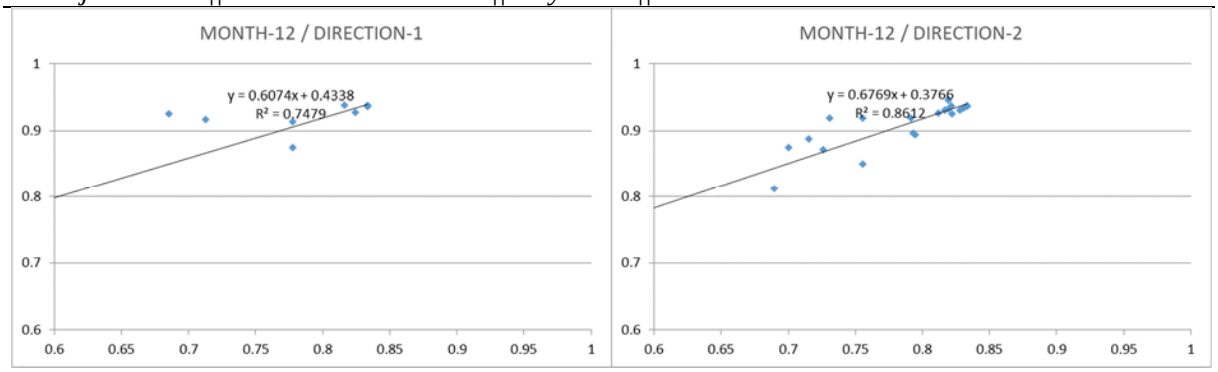

Figure-12: Time Period-12 Regression Analysis

Table-1: Model Values for Monthly Time Period

Time Period	Direction	PHF_{15}=a* PHF_{05}+b		Regression Coefficient R2 (%)
		a	b	
January	1	0.507	0.492	94.74%
	2	0.438	0.561	82.69%
February	1	0.340	0.653	57.79%
	2	0.130	0.822	9.25%
March	1	0.413	0.595	37.32%
	2	0.577	0.452	37.33%
April	1	0.592	0.446	58.49%
	2	0.443	0.569	47.75%
May	1	0.524	0.474	73.00%
	2	0.436	0.562	81.24%
June	1	0.407	0.598	72.69%
	2	0.048	0.971	0.90%
July	1	0.382	0.617	66.29%
	2	0.105	0.842	2.28%
August	1	0.409	0.598	73.61%
	2	0.322	0.668	42.70%
September	1	0.306	0.685	3.22%
	2	0.178	0.786	24.47%
October	1	0.305	0.687	45.41%
	2	0.350	0.650	46.97%
November	1	0.203	0.775	7.00%
	2	0.261	0.719	27.82%
December	1	0.607	0.434	74.79%
	2	0.677	0.377	86.12%

3.1.2 Peak Hour Factor Models for Weekdays

In the models created for the time period of the weekdays, PHF05 varies between 0.31-0.93 values and PHF15 values between 0.50-0.98. The fact that the PHF05 and PHF15 time slots in the direction-1 lanes are higher than 0.80 is due to the more regular traffic flow. In the 2 direction lanes, the PHF intervals are different. PHF range is wider in the 1st, 4th and 5th lanes, the range is narrower in the 2nd and 3rd lanes. A wider range of PHF values means that the traffic flow is more erratic. In addition, the regression coefficients in the 1st direction on weekdays are between 30-60%. Therefore, the model cannot explain reality. Although the regression coefficient is high in lanes 1, 4 and 5 in the 2nd direction, the same interpretation cannot be made for the entire direction. The reason why the stability in the traffic flow varies greatly according to the lanes is the variety of vehicles.

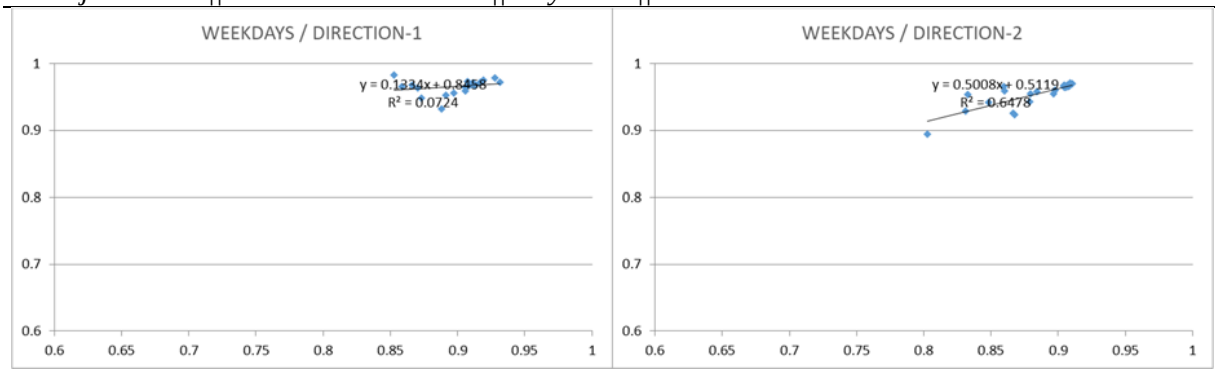

Figure-13: Time Period-13 Regression Analysis

Table-2: Model Values for Weekdays Time Period

Time Period	Direction	PHF_{15}=a* PHF_{05}+b		Regression Coefficient R2 (%)
		a	b	
Weekdays	1	0.133	0.846	72.40%
	2	0.501	0.512	64.78%

3.1.3 Peak Hour Factor Models for Weekends

In the models created for the time period of the weekend days, PHF05 varies between 0.33-1 values and PHF15 values between 0.67-1. The fact that the values of the PHF05 and PHF15 time periods in the direction-1 lanes are close to each other is due to the more regular traffic flow. In the 2nd direction, the situation is not as stable as in the 1st direction. There is a different situation according to the lanes, as in the case of the time period on weekdays. PHF models in lanes 1, 4 and 5, which are the same lanes, show the same behavior. The same is true for regression analysis. While the 1st, 4th and 5th lanes are regular, the traffic behavior models in the 2nd and 3rd lanes do not give accurate results. The reason why the stability in the traffic flow varies greatly according to the lanes is the variety of vehicles.

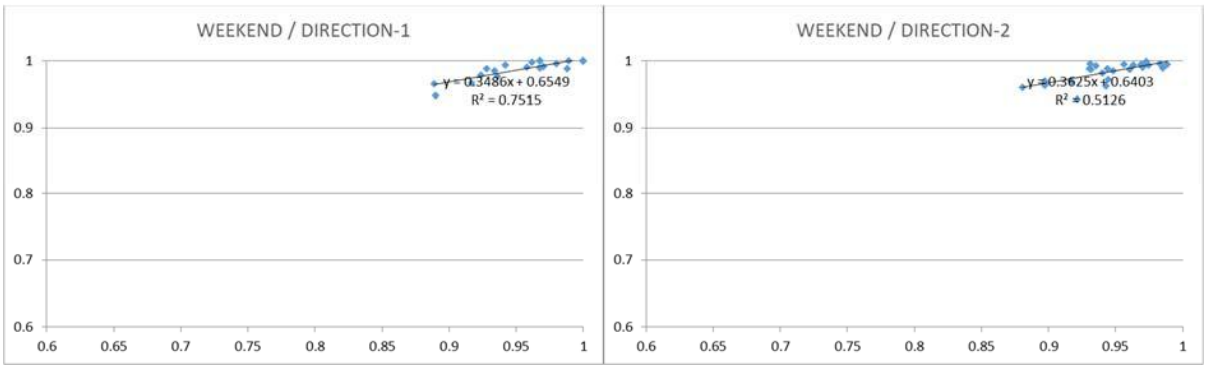

Figure-14: Time Period-14 Regression Analysis

Table-3: Model Values for Weekend Time Period

Time Period	Direction	PHF_{15}=a* PHF_{05}+b		Regression Coefficient R2 (%)
		a	b	
Weekends	1	0.349	0.655	75.15%
	2	0.362	0.640	51.26%

4. Conclusion

Considering the PHF values calculated according to different time periods there are variations between short-term and long-term PHF time periods. Short-term measures (hourly, daily, etc.) reveal increased instability in vehicular use of lanes and directions. When longer time periods, such as monthly intervals, are concerned, the relationships seem more consistent and successful.

Also it is seen that PHF values in winter, autumn and spring are more consistent than summer months, and the regression coefficients are higher. Although the reliability of the results obtained from the monthly PHF calculations is higher than the daily calculations.

Calculated for two directions of the section over a time period. The model gets more accurate for "a" values of the models vehicular traffic gets dense, especially PHF values greater than 0.65. In point of "b" which is shifting factor, it is clear to approach "0" while PHF values get more closer to "1" value which shows regular traffic flow. So it must be noted that both 05 minute and 15 minute PHF values differs each other in low volume roads and irregular flows because their minimum values are 1/12 and ¼ respectively.

When the regression coefficients for weekdays and weekends are compared, the coefficient in the direction 1 is higher, so the model in the direction 1 gives more reliable results. There are also strong correlations on a monthly basis. Strong correlations also appear on month base. The months with the highest regression coefficients and consequently the months having the strongest PHF relations are January, May, and December.

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