Investigation of Direction based Microscopic Traffic Stream Parameters for Ankara-Polatlı State Highway-Polatlı Direction

Dr. Hikmet Bayırtepe[1], Fatma Büyükbayram Uzuncan[2]

[1]Associate Professor Dr., Department of Civil Engineering, Faculty of Engineering,
Gazi University, Turkey
[2]Graduate School of Natural and Applied Sciences, Gazi University, Turkey

Abstract: Ankara is the capital and one of the most populous cities of the Republic of Turkey. The Ankara-Polatlı state road connects Ankara with western and southern Turkey and is one of the most important state roads in Turkey. Therefore, it is a critical highway section, not only for Ankara but also for Turkey. Thus, the contribution of improvements to this highway is significant for Turkey. Traffic data was recorded by the traffic cameras on the Ankara-Polatlı State Highway. This data includes the time and velocity of vehicle crossings in the Polatlı direction. By performing vehicle flow analyses for the Polatlı direction on this state road, which operates as a 2x3 divided road, the traffic flow characteristics and the status of traffic flow are revealed. The outcomes can be evaluated for management and future transportation operations.

Keywords: Traffic stream, traffic stream characteristics, microscopic flow, traffic data processing

1. Introduction

Camera systems installed by the General Directorate of Highways on state highways are used to measure traffic on highway directions and lanes. Highway traffic is recorded to be used in many different studies. These data include vehicle movements in the relevant lanes of the highway section, entering and exiting the camera footage, date and time of passage for each vehicle by distance and time, velocity, direction, lane use and vehicle type.

Macroscopic flow determines the characteristics of the overall road section, such as flow, average velocity and density. Microscopic flow analysis makes traffic analysis more user-specific. Microscopic flow analysis analyzes traffic for each vehicle individually, and the results of microscopic flow analysis are based on vehicles.

Microscopic traffic characteristics are studied based on of vehicle followings observed over the whole year of 2022 with respect to the evaluation of traffic in each existing lane. Within the scope of this study, only the Polatlı direction of the Ankara-Polatlı State Highway and its traffic data gathered by a camera system named No: 80 have been analyzed for microscopic flow parameters and features.

2. Materials and Method

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

2.1 Basic Knowledge

2.1.1 Traffic Stream and Its Parameters

A Traffic stream is the situation that includes all components of traffic consisting of pedestrians, drivers, vehicles, roads, signs and environmental effects and appears 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, affects the traffic stream. Traffic stream parameters are separated into two categories: macroscopic parameters and microscopic parameters. Macroscopic parameters of the traffic stream are flow, average velocity, and density. The microscopic parameters of the traffic stream are time headway, space headway and the velocity of each car.

2.2 Row Data and Data Processing

In this study, the data recorded by the General Directorate of Highways (KGM) camera systems on the Ankara-Polatlı State Highway 80 are used. The data includes the passage time and vehicle velocities of the vehicles passing through the section according to the direction and lane designations determined by KGM.

The Polatlı-Ankara State Highway Section is a 2x3 divided highway, and direction-lane numbering is shown in Figure 3.1. There are lanes numbered 3,4 and 5 in the 1st direction and lanes numbered 0,1 and 2 in the 0th direction.
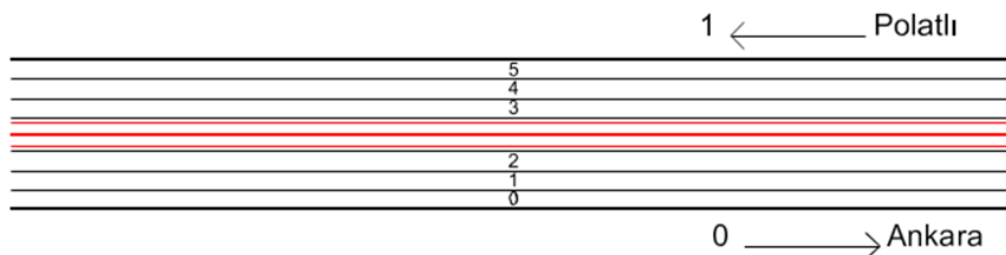
Figure-1: Ankara-Polatlı 80. Section Sketch

In this study, traffic data recorded by KGM on the Ankara-Polatlı State Highway Section with camera systems numbered 80 for the whole year 2022 will be used. By using the vehicle crossing date and time, direction of movement, velocity and lane information recorded for 1 year, separate working databases for each direction for the 2022 year, months, days of the week, and hours of the day have been generated. Based on these databases, microscopic flow analyses will be performed for the Polatlı direction. The results of the statistical procedures will be evaluated and the traffic behavior on this road section will be investigated.

3. Results

3.1 Data Analysis

A database was generated with the vehicle passing times obtained from the data sets created with the measurements. The database includes vehicle velocity, time headways and space headways between vehicles. Time headway data is obtained from the difference between the passing times of vehicles. Space headway values are also calculated using passing times and vehicle velocities. The database to be used in this study is created in this way.

This study uses data obtained from traffic counts in both directions on the Ankara-Polatlı state highway in 2022. A total of 10,713,625 vehicle crossings were recorded on this road in 2022.5,398,105 vehicles belong to Ankara-Polatlı direction, and 5,315,520 vehicles belong to the Polatlı-Ankara direction.

3.1.1 Traffic Stream Statistics for Both Direction

On the Ankara-Polatlı state highway, the average velocity in 2022 is 101.84 km/h, and the median is 101. The fact that the mean and median are very close shows the reliability of the data set. The minimum velocity is 5 km/h, and the maximum velocity is 249. The standard deviation is 19.69. The reason for the high standard deviation is considered to be different vehicle types, different seasons and weather conditions, variable traffic conditions, etc.

On the Ankara-Polatlı state highway in 2022, the time headway is 18.7 seconds, and the median is 10 seconds. The minimum time headway is 1 second, and the maximum time headway is 18987 seconds. The standard deviation is 38.80. The high standard deviation, the significant difference between the mean and the median, and the fact that the mean is close to the 3rd quartile means that there is an accumulation of low time headway values. However, the high time headways are very high in discrete time headways. This is especially at night and in the morning when traffic volume is low. Thus, this shows that the traffic distribution is not uniform.

On the Ankara-Polatlı state road in 2022, the space headway is 533 meters, and the median is 271 meters. The minimum space headway is 5.83 meters and the maximum time headway is 474,675 meters. The standard deviation is 1247. The high standard deviation, the significant difference between the mean and median, and the fact that the mean is close to the 3rd quartile indicate there is an aggregation in low space headways but high time headways are very high in isolation. The distances between vehicles on this road section are more than 1 vehicle even in the minimum case. Therefore, the level of service on this road is high.

Table-1: Ankara-Polatlı State Highway Statistical Values

Variable	N	Mean	StDev	Minimum	Q1	Median	Q3	Maximum
V	10713625	101.84	19.69	5	88	101	114	249
Ht	10713625	18.7	38.8	1	5	10	20	18987
Hs	10713625	533	1247	5.83	142	271	547	474675

3.1.2 Traffic Stream for Polatlı Direction

On the Ankara-Polatlı state highway direction-1, the average velocity in 2022 is 100.27 km/h, and the median is 99. So the mean and the median are very close, showing the reliability of the data set. The minimum velocity is 9 km/h, and the maximum velocity is 249. The standard deviation is 19.09. High standard deviation is high for this data set. Reasons for this include different vehicle types, seasons and weather conditions, variable traffic conditions, etc.

On the Polatlı direction in 2022, the time headway is 18.50 seconds and the median is 10 seconds. The minimum time headway is 1 second, and the maximum time headway is 18,987 seconds. The standard deviation is 40.10, and the standard deviation is very high. The main reason for this is the different volumes at different times of the day and constantly changing traffic volumes. This indicates that there is an inconsistent flow of traffic.

On the Polatlı direction in 2022, the space headway is 519 meters, and the median is 264 meters. The minimum space headway is 6.67meters, the maximum time headway is 474,675 meters. The standard deviation is 1253, and it is very high. This shows that the traffic distribution during the day is not consistent. In addition, the high average velocity and the high space headway indicate that the traffic density is low.

Table-2: Direction-1 Statistical Values

Variable	N	Mean	StDev	Minimum	Q1	Median	Q3	Maximum
V	5398105	100.27	19.09	9	87	99	112	249
Ht	5398105	18.5	40.1	1	5	10	20	18987
Hs	5398105	519	1253	6.67	139	264	529	474675

Monthly measurements of traffic in direction 1 are given in Table-3. Monthly numbers in this table are given from January to December. On the Ankara Polatlı state highway in Polatlı direction, the highest number of vehicles were measured in July and August, which are the 7th and 8th months in 2022. The lowest volume is in February, which is the 2nd month. Monthly average velocities are close to each other. The highest average velocity is 104.34 in month 8 and the lowest average velocity is 98.74 in month 3. The monthly medians for velocity are very close to the averages. Standard deviations for all months are close to each other. These figures show that monthly vehicle usage, vehicle distribution, driver behavior, traffic trends and level of service are similar.

The month with the highest average in time headways on a monthly basis is January with 25.30 seconds, while the month with the lowest average is July with 13.81 seconds. There is a significant difference between the median and the mean for time headways. Averages are closer to Q3. This is because relatively low values are accumulated, the distribution of high values is dispersed, and high values are very high. Therefore, the mean values for time headway are not reliable enough. When the mean, median and Q3 are evaluated together, the highest time headway is in January, and the lowest time headway is in July. Although the values are not reliable, the data produced for the lowest and highest time headway assessments by month of the year are consistent.

On a monthly basis, the month with the highest average in space headways is January with 714 meters, and the month with the lowest average is July with 398 meters. There is a significant difference between the median and the mean for time headways. Averages are closer to Q3. This is because relatively low values are accumulated, the distribution of high values is very dispersed and very high. This is in parallel with time headway measurements. When the mean, median and Q3 are evaluated together, the highest time headway is in January and the lowest time headway is in July. Although the values are not reliable, the data produced for the lowest and highest space headway assessments by month of the year are consistent. In this case, it is in parallel with the measurements and inferences made for time headway.

Table-3: Direction-1 Monthly Statistical Values

Variable	Month	N	Mean	St Dev	Minimum	Q1	Median	Q3
V	1	661487	100	19.91	9	86	99	112
	2	636542	99.588	19.697	10	85	98	111
	3	701879	98.742	19.759	6	85	97	110
	4	744244	99.755	19.753	10	86	98	111
	5	921480	101.35	19.05	10	88	100	113
	6	878323	100.82	19.56	9	87	100	113
	7	1255008	103.98	18.5	7	92	103	115
	8	1237549	104.34	19.47	17	91	104	116
	9	1062188	103.5	19.77	5	90	103	115
	10	924584	102.5	20.16	14	88	101	115
	11	877591	101.74	20.02	10	87	101	114
	12	812750	101.45	20.36	9	87	100	114
Ht	1	661487	25.3	68.3	1	6	12	26
	2	636542	23.8	53.28	1	6	12	25
	3	701879	23.9	53.89	1	6	12	25
	4	744244	21.9	44.28	1	6	11	23
	5	921480	18.44	35.31	1	5	10	20
	6	878323	18.71	33.77	1	5	10	21
	7	1255008	13.81	21.82	1	4	8	15
	8	1237549	13.99	20.74	1	4	8	16
	9	1062188	15.64	25.84	1	5	9	17
	10	924584	18.38	34.19	1	5	10	20
	11	877591	18.72	36.21	1	5	10	20
	12	812750	20.77	40.96	1	6	11	22
Hs	1	661487	714	2116	5.83	168	333	688
	2	636542	672	1736	10	167	325	666
	3	701879	673	1753	13.9	167	327	664
	4	744244	623	1470	10.8	154	303	626
	5	921480	527.7	1154.7	7.22	138.9	267.2	541.7
	6	878323	533	1099	10	148	282	560
	7	1255008	398.1	680.3	7.22	118.9	219.7	431.1
	8	1237549	404.2	653.5	8.33	125	229.2	444.4
	9	1062188	450.6	826.8	14.7	132.2	246.7	483.3
	10	924584	527	1104	10	146	276	550
	11	877591	535	1180	6.67	145	275	550
	12	812750	593	1328	10.6	157	303	609

Daily measurements of traffic for a week in direction 1 are given in Table-4. The highest number of vehicles on the Ankara Polatlı road in 2022 is Saturday with 1,652,981 vehicles in total. Average vehicle velocities are similar on the days of the week. The highest average velocity is 104.07 km/h on Sunday, and the lowest average velocity is 100.52 km/h on Tuesday. The median and mean are close, and the differences between these two variables are the same. The standard deviations for velocities of weekdays are high. The highest standard deviation is 20.17 for Tuesday, and the lowest standard deviation is 18.73 for Sunday. There are no major differences between the days of the week in terms of velocity.

When the time headways for the days of the week are analyzed, it is seen that the highest time headway belongs to Tuesday with 19.79 seconds, and the lowest time headway belongs to Friday with 17.02 seconds. The time headways between vehicles are high, and vehicles do not follow each other closely. Considering the time headway at this level, the difference of 2-3 seconds is not significant. There is a large difference between the median and mean for time headway. The standard deviations are also large. This is due to the uneven

distribution of traffic during the day and week. Time headway is accumulated in certain data, and the maximum value is very high and dispersed from the accumulated data group. Therefore, the median and Q3 are more accurate than the mean. When the median and Q3 variables are evaluated, the first days of the week have higher values, and the last days have lower values.

Space headways for days of the week are high and similar. Likewise, time headway, median and Q3 values are more accurate than the average for space headway. When the mean, median and Q3 are evaluated, the lowest space headway is on Friday, day 5, and the highest space headway is on Monday, day 1. The lowest and highest standard deviations are also calculated for these days.

Table-4: Direction-1 Weekdays Statistical Values

Variable	Week Day	N	Mean	St Dev	Minimum	Q1	Median	Q3	Maximum
V	1	1428818	101.45	19.77	9	87	100	113	249
	2	1434838	100.52	20.17	9	86	99	113	249
	3	1467676	100.70	20.19	5	86	99	113	249
	4	1488905	100.83	20.21	6	86	99	113	249
	5	1683440	102.17	19.66	8	88	101	114	249
	6	1652981	102.82	18.97	8	90	102	114	249
	7	1556967	104.07	18.73	9	92	103	115	249
Ht	1	1428818	19.87	42.23	1	5	11	21	7447
	2	1434838	19.79	39.34	1	6	11	21	4050
	3	1467676	19.37	37.78	1	5	11	21	3714
	4	1488905	19.11	36.85	1	5	10	21	3947
	5	1683440	17.02	34.23	1	5	9	18	4156
	6	1652981	17.62	35.16	1	5	9	19	5571
	7	1556967	18.30	45.4	1	5	9	19	18987
Hs	1	1428818	568	1337	12.80	151	290	581	156562
	2	1434838	562	1273	7.22	152	290	578	123505
	3	1467676	551	1241	10.00	149	285	568	169193
	4	1488905	543	1198	9.72	149	284	564	147542
	5	1683440	485	1112	6.67	135	254	506	154601
	6	1652981	504	1125	10.80	133	253	517	194985
	7	1556967	528	1434	5.83	131	250	519	474675

Hourly measurements of traffic of a day in direction 1 are given in Table-5. Measurements for the hours of the day show that the highest usage during the day is 17-18 with 741,289 vehicles. 13-19 is the interval with the highest usage. The lowest usage is 02-03 at night 117,991 vehicles. The lowest usage is 01-05 hours. In parallel, the average velocity is highest at 17-18 hours at 103.66 km/h. The lowest average velocity is 00-01 with 98.76 km/h. Median values for velocity are close to the mean. The standard deviation for velocity is close and high for all hours.

Time headway in the time of day is highest at 02-03 with 67.41 seconds and lowest at 17-18 with 11.63 seconds. There is a significant difference between the mean and median values for time headway. The mean is close to Q3. In addition, considering the high standard deviation, the distribution in the dataset is not homogeneous. However, when the mean, median and Q3 are evaluated together, the data distribution during the day is consistent.

On hourly basis, the hours with the highest average in space headways is 02-03, 1910 meters and the hours with the lowest average is 17-18, 333 meters. There is a significant difference between the median and the mean for time headways. Averages are closer to Q3. This is because relatively low values are accumulated, the distribution of high values is very dispersed, and high values are very high. So the distribution is not homogeneous, and it is parallel with time headway measurements. The mean, median and Q3 are evaluated, the highest time headway is at 02-03 and the lowest time headway is in July. Although the values are not reliable, the data produced for the lowest and highest space headway assessments by month of the year are consistent. In this case, in parallel with the measurements and inferences made for time headway.

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Table-5: Direction-1 Hourly Statistical Values

Variable	Hr	N	Mean	St Dev	Minimum	Q1	Median	Q3	Maximum
V	0	200772	98.76	20.75	10.0	84.0	96.0	110.0	248.0
	1	142690	98.86	20.68	9.0	84.0	97.0	110.0	249.0
	2	117991	98.77	20.56	7.0	84.0	97.0	110.0	242.0
	3	127639	98.96	19.73	12.0	85.0	97.0	110.0	234.0
	4	172678	100.11	19.71	9.0	87.0	98.0	111.0	249.0
	5	263162	101.33	19.24	10.0	89.0	100.0	112.0	249.0
	6	450366	102.12	18.92	6.0	89.0	100.0	113.0	249.0
	7	498395	102.79	19.27	9.0	90.0	102.0	114.0	249.0
	8	507758	101.90	19.34	8.0	88.0	101.0	113.0	247.0
	9	547078	101.44	18.96	14.0	88.0	101.0	113.0	248.0
	10	573312	101.25	18.97	12.0	88.0	100.0	113.0	249.0
	11	594769	101.68	19.15	15.0	88.0	101.0	113.0	249.0
	12	581243	101.99	19.31	10.0	88.0	101.0	113.0	248.0
	13	610882	101.98	19.24	9.0	88.0	101.0	113.0	246.0
	14	656126	102.01	19.22	5.0	88.0	101.0	113.0	247.0
	15	691589	102.94	19.34	10.0	89.0	102.0	114.0	249.0
	16	729719	103.49	19.58	16.0	90.0	103.0	115.0	249.0
	17	741289	103.66	19.69	19.0	90.0	103.0	115.0	248.0
	18	603779	103.47	20.31	12.0	89.0	103.0	116.0	248.0
	19	497877	102.11	20.54	13.0	87.1	101.0	115.0	248.0
	20	425140	101.27	20.66	19.0	86.0	100.0	114.0	249.0
	21	375659	100.44	20.68	14.0	85.0	99.0	113.0	248.0
	22	334931	99.06	20.47	18.0	84.0	97.0	111.0	249.0
	23	268781	98.94	20.67	10.0	84.0	97.0	111.0	249.0
Ht	0	200772	39.76	67.06	1.0	9.0	20.0	44.0	2715.0
	1	142690	55.39	104.42	1.0	11.0	27.0	60.0	7447.0
	2	117991	67.41	138.27	1.0	13.0	30.0	70.0	5571.0
	3	127639	63.15	133.64	1.0	12.0	28.0	64.0	4700.0
	4	172678	47.55	104.66	1.0	9.0	21.0	49.0	5578.0
	5	263162	31.20	60.60	1.0	7.0	15.0	33.0	3905.0
	6	450366	18.70	42.00	1.0	5.0	10.0	21.0	18987.0
	7	498395	16.83	24.60	1.0	5.0	10.0	20.0	2427.0
	8	507758	16.54	24.83	1.0	5.0	10.0	19.0	4006.0
	9	547078	15.41	21.76	1.0	5.0	9.0	18.0	1256.0
	10	573312	14.77	19.91	1.0	5.0	9.0	18.0	3433.0
	11	594769	14.24	18.55	1.0	5.0	9.0	17.0	4062.0
	12	581243	14.58	19.34	1.0	5.0	9.0	17.0	3006.0
	13	610882	13.92	17.14	1.0	5.0	9.0	17.0	4035.0
	14	656126	13.02	14.56	1.0	5.0	8.0	16.0	471.0
	15	691589	12.40	13.44	1.0	4.0	8.0	15.0	347.0
	16	729719	11.81	12.67	1.0	4.0	8.0	14.0	527.0
	17	741289	11.63	12.71	1.0	4.0	8.0	14.0	520.0
	18	603779	14.04	16.97	1.0	5.0	9.0	17.0	726.0
	19	497877	16.82	21.61	1.0	5.0	10.0	20.0	1060.0
	20	425140	19.52	26.17	1.0	6.0	11.0	23.0	1187.0
	21	375659	21.96	30.58	1.0	6.0	12.0	26.0	1619.0
	22	334931	24.49	35.36	1.0	7.0	14.0	29.0	1915.0
	23	268781	30.18	45.89	1.0	8.0	16.0	35.0	2737.0

	0	200772	1120.00	2186.00	10.8	247.0	539.0	1172.0	109354.0
	1	142690	1563.00	3371.00	14.4	310.0	708.0	1576.0	147542.0
	2	117991	1910.00	4603.00	15.6	347.0	816.0	1844.0	194985.0
	3	127639	1781.00	4370.00	16.1	315.0	742.0	1700.0	169193.0
	4	172678	1351.00	3449.00	13.9	245.0	565.0	1295.0	252559.0
	5	263162	890.00	1942.00	10.6	193.0	411.0	894.0	125987.0
	6	450366	537.00	1228.00	10.0	151.0	288.0	575.0	474675.0
	7	498395	488.70	811.30	10.8	145.8	277.5	542.5	68009.7
	8	507758	480.30	836.00	10.0	143.1	270.0	527.8	99037.2
	9	547078	445.60	733.20	9.7	134.7	253.3	491.9	42230.0
	10	573312	426.00	677.00	12.8	133.0	249.0	477.0	131598.0
Hs	11	594769	411.00	618.00	13.3	131.0	244.0	467.0	127502.0
	12	581243	422.00	636.00	5.8	135.0	251.0	478.0	109385.0
	13	610882	401.40	556.20	7.2	131.9	244.4	459.2	94150.0
	14	656126	373.50	473.00	10.8	127.8	232.5	434.4	16575.0
	15	691589	356.80	431.90	7.2	125.6	225.0	418.9	16012.5
	16	729719	339.40	400.80	13.1	121.1	217.5	401.4	17859.4
	17	741289	332.80	391.70	6.7	118.9	212.5	394.2	13275.0
	18	603779	400.90	530.10	13.9	130.6	242.2	466.7	28186.1
	19	497877	475.20	670.00	13.9	143.1	272.5	546.7	22759.4
	20	425140	550.00	824.50	13.6	156.9	306.9	622.5	44766.7
	21	375659	618.00	975.50	8.3	168.9	337.5	693.3	61611.9
	22	334931	683.10	1123.00	13.1	185.0	368.9	756.9	62241.1
	23	268781	846.30	1468.40	13.3	212.5	438.1	916.1	80589.4

4. Conclusion

The purpose of this paper is to examine the microscopic traffic behavior for different time intervals in one direction of the 2x3 divided Ankara-Polatlı highway, one of the most important intercity state highways in Turkey, independently of the effects such as vehicle type, seasonal effects, environmental effects, driver effects, and also examine the microscopic flow of traffic on this road.

Microscopic traffic analyzed at different time periods on the Polatlı direction of the Ankara-Polatlı state highway showed that the velocities were high and close to the free flow velocity of 110 km/h. In addition, velocity and median are close. Therefore, the distribution of the velocity data obtained is close to the normal distribution. Also, the standard deviation of the velocity is high. The most important reason is the different types of vehicles in this highway section. There are also wide differences between the maximum and minimum of velocity. The reason is the variable traffic conditions at different times of the day.

Time headway and space headway calculations reveal very similar situations. Therefore, these microscopic evaluations based on vehicle tracking are consistent. Time headway and space headway calculations show that the differences between vehicles following each other are high. The mean values are close to the Q3 (third quarter) value, not the median. Thus, it can be concluded that vehicles generally move closer to each other than the average. In the following values, there are accumulations at values lower than the mean, and very high values at the maximum, which is also supported by the very high standard deviations.

The velocity, time headway, and space headway results are similar and compatible on the basis of annual, monthly, day of the week, and hourly data. The fact that different variables give compatible results in different time periods proves the accuracy of the study and evaluations.

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