Daily flow profiles of urban traffic

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Abstract

The estimation of Average Annual Daily Traffic (AADT) on the basis of short-term traffic counts provides some insight into seasonal and day-to-day variability of urban traffic flows. The insight into the differences in daily flow profiles between weekdays is however limited. In this contribution, daily flow profiles on a main route in a city in The Netherlands are analysed. As well the total amount of traffic as the shapes of the daily profiles are compared for various weekdays. The differences are analysed both qualitatively and quantitatively using ANOVA analysis.

From the study it can be concluded that the daily flow profile varies throughout the week. Sunday shows a dissimilar flow profile compared to weekdays. Also the weekdays show mutual differences. On Friday, the daily flow profile is less peaked than on Monday and Tuesday. Furthermore, on Monday, the off-peak traffic flow and evening peak flow are lower than on other weekdays, resulting in a lower daily traffic flow. The differences found are probably mainly caused by variations in activity patterns. The results of this study have implications for the implementation of traffic management tools, such as traffic signals. Furthermore, the obtained insight can be used for the further development of travel demand management. Finally, when traffic is counted during a limited period of the day, the differences between the daily flow profiles of weekdays have to be taken into account.
Keywords: traffic flow variability, daily flow profile, AADT, ANOVA, urban traffic system.

1 Introduction

For the estimation of the Average Annual Daily Traffic (AADT), 24-hour traffic counts are usually adjusted based on the season and day of the week [1, 2, 3, 4]. Schmidt [5] also discusses the correction for the time of the day on typical

weekdays (Tuesday-Thursday) and Sundays. Furthermore, when correcting the total daily traffic flow, Schmidt distinguishes core weekdays (Tuesday–Thursday), Mondays, Fridays, Saturdays and Sundays.

Fox and Clark [6] state that mean flows on Saturdays and Sundays are both distinct from one another and are lower than during the rest of the week. For weekdays, they found the flows to be very similar to each other, although they state it is very common for the flows on one or two weekdays to be slightly different due to a market day or late-night shopping.

Stathopoulos and Karlaftis [7] studied the seasonal, weekly and time of the day variations in traffic flows in Athens. Since they concluded that traffic does not follow a Normal distribution, they used Wilcoxon nonparametric tests to investigate whether differences are significant. Weekends turned out to differ from weekdays and Saturdays were found to differ from Sundays. No significant differences were found between weekdays. According to the time of the day, they concluded that average weekday traffic flows are different for most time periods (0:00–6:30; 6:30-10:00; 10:00–13:30; 13:30-17:00; 17:00-20:30; 20:30-0:00). For the 10:00–13:30 and 13:30–17:00 time periods traffic flows do not differ significant, but the main direction of travel does.

Rakha and Van Aerde [8] studied the variability in traffic conditions on freeways. They concluded that traffic flow conditions are highly similar between and within core weekdays (Tuesday-Thursday). Furthermore, some traffic flow parameters on Mondays are similar to core weekdays, but from an ANOVA analysis they concluded that Monday flow conditions were statistically significant from core weekdays. On Fridays, the p.m. peak appears to extend further in the day and the ANOVA analysis indicates that the flow on Fridays is statistically different from core weekdays.

From this literature review it can be concluded that there is some knowledge about seasonal and weekly variations in urban traffic flows. The comparison between weekdays however mainly exists of comparing the total daily traffic. The insight into the differences in daily flow profiles between weekdays is limited. Rakha and Van Aerde did some research into variations in daily flow profile, but their study focussed on the highway system.

As well for traffic management purposes as for adjusting short-term traffic counts, it is desirable to obtain more insight into the differences in daily flow profiles between weekdays. In this paper, the daily flow profiles on a main route through the city of Almelo are compared for various days of the week. First the study area is described. Next, the method of analysis is outlined. Then the results of the analysis are presented. Furthermore possible explanations are outlined and finally some conclusions are drawn and recommendations are given.

2   Study area and data

The study area consists of a main route through the city of Almelo, the Weezebeeksingel – H. Roland Holstlaan. Almelo is a city in the east of the Netherlands with roughly 71.000 inhabitants. The route is mainly used by regional traffic and connects villages near Almelo with the highway. The

Weezebeeksingel also serves as a collector for traffic from residential areas along the route. The H. Roland Holstlaan is mainly surrounded by industrial areas. Finally, also a hospital, a furniture mall and a soccer stadium are located along the route. Figure 1 shows the study area.
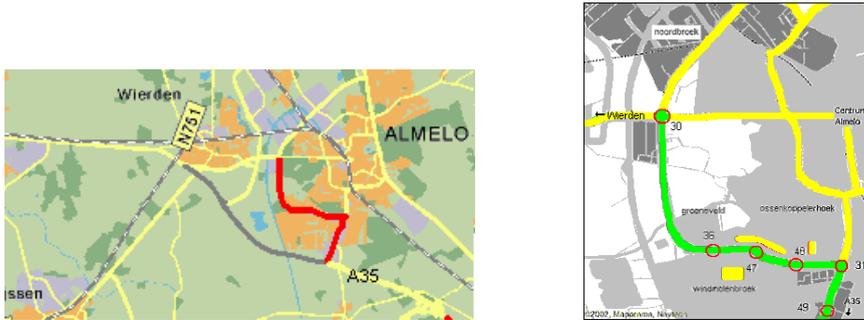
Figure 1:   Study area.

On the route, traffic is controlled by six signalised intersections with vehicle-actuated control. At these intersections, traffic is detected by induction loops. The detector data is logged and used for analysis in this research. All the data are collected in the period July – October 2002. Some of the data is collected during Summer Holidays. These data are excluded from the analysis. In table 1 an overview is given of the available data per intersection.

Table 1:   Available data.

Intersection	Number of days data is collected	Period of the day traffic is detected	Days of the week
30	17	24 hours a day	Sun, Mon, Tue
36	22	24 hours a day	Sun, Mon, Tue
47	24	7:00A.M–7:00P.M	Mon, Tue, Thu, Fri
48	30	7:00A.M–7:00P.M	Mon, Tue, Thu, Fri
31	29	7:00A.M–7:00P.M	Mon, Tue, Thu, Fri

The data is aggregated into hourly traffic flows. The hourly traffic flows at an intersection are verified using data from the other intersections. The amount of traffic detected at intersections 47 and 48 turned out to be incorrect, probably because of broken detectors. The average hourly traffic flow at these intersections is therefore corrected on basis of the hourly traffic flow at intersection 31.

3   Method

As well the total intersection flows as the traffic on the main route and the traffic towards the city centre are analysed. First, the total daily traffic is compared for

the various weekdays. Secondly, also the daily flow profiles are compared. For the comparison of the daily flow profiles, the day is divided into the following time periods:

- Morning peak; two successive busiest hours in the morning; 7:00 – 9:00
- Morning off-peak period: 9:00 – 12:00
- Afternoon off-peak period: 13:00 – 16:00
- Evening peak: two successive busiest hours in the late afternoon; 16:00-18:00.

Both the amount of traffic during these time periods and the ratios between the time periods are compared for the different weekdays. In this way, both the amount of traffic and the shape of the daily flow profile are taken into account.

The differences between the amount of traffic and the ratios between time periods are analysed both qualitatively and quantitatively using ANOVA analysis. The Kolmogorov-Smirnov and Shapiro-Wilk tests are used to decide whether a Normal distribution of the traffic flows can be assumed and ANOVA analysis thus is allowed. Since traffic flows on intersections 47 and 48 are corrected using data from intersection 31, daily flow profiles are analysed only qualitatively on these intersections.

4   Results

4.1 Comparison of Sunday and weekdays

As expected, Sunday shows a dissimilar daily flow profile. Daily flow profiles are comparable for both intersections and for the main route. The traffic to and from the city centre shows a somewhat dissimilar flow profile with a relative high morning peak towards the city centre and a relative high evening peak in the opposite direction. Figure 2 shows the daily flow profiles on intersection 36.
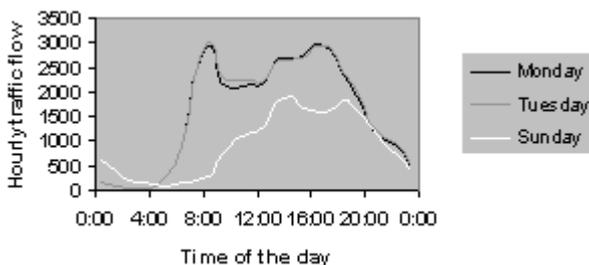

Figure 2:   Average daily flow profile at intersection 36.

From the ANOVA analysis can be concluded that the total daily traffic is significantly lower on Sunday compared to Monday and Tuesday. Furthermore, during all time periods at all locations, traffic flow is significantly lower on Sunday (also see table 2). Also most ratios differ between Sunday and the

analysed weekdays. At intersection 36 and between the intersections however, no significant differences are found regarding the ratio P.M. peak/off-peak period.

Table 2:   Comparison between Sunday and weekdays.

Sunday/average weekday	Daily flow[1]	A.M. peak	Off-peak	P.M. peak
Intersection 30	1.72	10.31	1.68	1.83
Intersection 36	1.70	9.95	1.73	1.77
Flow towards highway	1.64	11.40	1.63	1.73
Flow from highway	1.66	8.56	1.69	1.69
Flow towards city centre	1.78	14.23	1.76	1.68
Flow from city centre	1.79	7.67	1.72	2.11

[1]24-hour flow

4.2 Comparison between weekdays

The differences between Sunday and weekdays were as expected. More interesting is the comparison of the daily flow profiles between weekdays. Also between the weekdays, differences appear to exist concerning the daily flow profiles, although the differences are not as large as between weekdays and Sunday. The average daily flow profiles at intersection 31 are shown in figure 3. The other analysed traffic flows show a similar profile.
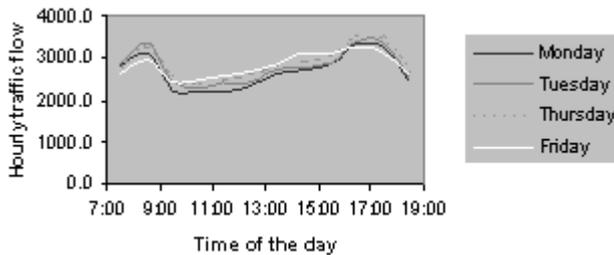

Figure 3:   Average daily flow profiles at intersection 31.

4.2.1   Comparison of total daily flow
The total daily intersection flow turns out to be lowest on Monday and highest on Thursday. Furthermore, on Friday, the total daily traffic is a little higher than on Tuesday. Table 3 shows the average daily traffic flow on the analysed locations.

From the ANOVA analysis regarding intersection 31 can be concluded that the amount of traffic is significantly lower on Monday compared to Thursday and Friday. Also for the analysed sub flows, significant differences are found between Monday and other days. The results from the ANOVA analysis are summarized in table 4.

Table 3:   Average daily traffic.

Total daily flow[1]	Monday	Tuesday	Thursday	Friday
Intersection 47	24989	26000	26913	26244
Intersection 48	25710	26611	27429	27325
Intersection 31	32097	33447	34604	33890
Towards highway[2]	11311	11796	12282	11808
From highway[3]	10686	11112	11529	11385
Towards city centre	7376	7611	7907	7871
From city centre	7816	8089	8234	8212

[1]From 7:00 to 19:00
[2]Average of flows between intersections 36 and 47, 47 and 48, 48 and 31, 31
 and highway
[3]Average of flows between highway and 31, 31 and 48, 48 and 47, 47 and 36

Table 4:   ANOVA analysis total daily traffic.

Flow	Test of Normality	Daily flow
Intersection 31	All days passed	Mon lower than Thu and Fri
Towards A35	Thu did not pass	Mon lower than Thu
From A35	Tue + Thu did not pass	Mon lower than Thu
Towards centre	All days passed	Mon lower than Thu and Fri
		Tue lower than Thu
From centre	Tue + Fri did not pass	Mon lower than Thu

4.2.2   Comparison of morning peak, off-peak and evening peak flows

Also the daily flow profile varies throughout the week. To show differences in traffic flows between weekdays, ratios are calculated between weekdays for the various time periods. Table 5 shows these ratios.

Table 5:   Average ratios between weekdays (average value, resulting from intersections 47, 48 and 31).

Period	Mon/ Tue	Mon/ Thu	Mon/ Fri	Tue/ Thu	Tue/ Fri	Thu/ Fri
A.M. peak	0.97	0.99	1.07	1.02	1.11	1.08
Morning	0.93	0.89	0.87	0.97	0.95	0.98
Afternoon	0.98	0.93	0.90	0.95	0.93	0.97
P.M. peak	0.99	0.95	1.02	0.96	1.03	1.07

During the off-peak period, traffic flow is highest on Friday. During the peak periods, traffic flow is generally lowest on Friday. For most directions the morning peak is highest on Tuesday and lowest on Friday. Towards the city centre, the A.M. peak is highest on Thursday and lowest on Monday. The evening peak is highest on Thursday and lowest on Friday for most directions. For the traffic from the highway and the traffic towards the city centre however, the evening peak is lowest on Monday.

In most cases the ANOVA analysis shows a significant difference between the off-peak flow at the beginning and at the end of the week. On intersection 31, the off-peak flow on Monday is significantly lower than on Thursday and Friday and the off-peak flow on Tuesday is significantly lower than on Friday. The results of the ANOVA analyses are summarized in table 6.

Table 6:   Results ANOVA analysis traffic flows.

	Test of Normality[1]	A.M. peak	Off-peak	P.M. peak
31		Fri lower[2]	Mon lower Thu, Fri Fri higher Tue	Fri, Mon lower Thu
Towards highway		Fri lower	Mon lower Thu, Fri Fri higher Tue	Fri lower Thu
From highway	Tue off-peak Thu P.M peak	Fri lower Tue, Thu	Mon lower Thu, Fri	
Towards centre	Tue off-peak Thu P.M. peak	Fri lower Mon lower Tue, Thu	Mon lower Thu, Fri Fri higher Tue	
Centre→31	Mon off-peak Tue off-peak	Fri lower Tue	Fri higher	Fri lower Tue, Thu

[1]Periods that did not pass
[2]Friday A.M. peak is significantly lower than Monday, Tuesday and Thursday A.M. peak

In general, the Friday morning peak is found to be significantly lower than the morning peak on other weekdays. For the traffic towards the city centre, next to Friday morning peak, also Monday morning peak is significantly lower than the morning peak on Tuesday and Thursday. The evening peak is not in all cases lower on Friday. For the traffic from the highway and the traffic towards the city centre, no significant differences are found in P.M. peak traffic.

4.2.3   Comparison of shapes of the daily flow profile

Table 7 shows the ratios between the time periods on the analysed weekdays. The ratios between the peak traffic and the off-peak traffic decrease throughout the week, resulting in a less peaked profile on Friday compared to Monday. Also for the analysed sub flows, the daily flow profiles of Friday and Thursday are less peaked than the daily flow profiles of Monday and Tuesday.

The ratio between the morning and afternoon appears to be a little lower at Monday compared to other days. Also for most analysed sub flows this is the case. For the traffic from the city centre and the traffic from intersection 31 towards the highway, the ratios between morning and afternoon traffic are lowest on Thursday.

Table 7:   Comparison of ratios between days of the week (average value, resulting from intersections 47, 48 and 31).

Weekday	A.M./P.M. peak	A.M./ off-peak	P.M/ off-peak	Morning/afternoon
Monday	0.87	1.14	1.31	0.79
Tuesday	0.90	1.13	1.27	0.85
Thursday	0.84	1.06	1.27	0.83
Friday	0.84	0.95	1.14	0.84

ANOVA analyses are used to investigate whether the differences in ratios between weekdays are significant. The results of these analyses are summarized in table 8.

Table 8:   ANOVA analyses ratios.

	Test of Normality	A.M. peak/off-peak	P.M./off-peak	Morning/ afternoon
31		Fri lower Thu lower Mon, Tue	Fri lower	Mon lower Tue
Towards highway	Fri mor/aft	Fri lower Thu lower Mon	Fri lower	Tue higher Thu
From highway	All Tue ratios Fri mor/aft	Fri lower Mon, Tue Thu lower Tue		
31→centre	Mon P.M./off-peak	Fri lower Thu lower Tue	Fri lower	Mon, Fri lower Tue, Thu
Centre→31		Fri lower	Fri lower	

For most directions, except from the traffic from the highway, both the A.M. peak/off-peak and the P.M. peak/off-peak ratios are significantly lower on Friday compared to other weekdays. The ANOVA analysis for the morning/afternoon ratio does not lead to unambiguous results.

5   Possible explanations

People travel to be able to participate in activities. Possible explanations for variations in the amount of traffic can therefore be found in variations in activity patterns. Moreover, variations in travel behaviour (modal split, route choice, departure time) can also contribute to variations in traffic flows. Here, only explanations regarding variations in activity patterns are discussed.

Harms [9] studied the travel patterns of the Dutch population using the "Tijdsbestedingsonderzoek". This survey investigates how people allocate their time between different activities. Also Harms concludes that the daily flow profile on Sunday differs from the daily flow profile on weekdays. The absence

of commuter traffic combined with a relatively high percentage of leisure traffic on Sunday results in a dissimilar daily profile with a peak between 2:00 and 3:00 P.M.

Furthermore, Harms states that the daily flow profile is less peaked on Fridays compared to other weekdays. The dissimilar flow profile is caused by a relative low percentage of commuter traffic and a relative high percentage of leisure and household traffic. The relatively low amount of traffic on Monday morning can be explained by a relatively small amount of traffic concerning the household and children's care on this morning. Tuesday has the highest amount of commuter and educational traffic, accounting for the relatively high morning peak. The high evening peak on Thursday is not detected in the survey data. Probably late-night shopping in the city centre causes this relatively high peak.

6   Conclusions, discussion and recommendations

Monday can be concluded to be statistically different from Thursday and Friday and Friday can be concluded to be statistically different from Monday, Tuesday and Thursday. On Friday, the daily flow profile is less peaked than on Monday and Tuesday. On Monday, the off-peak traffic flow and evening peak flow are lower, also resulting in a lower daily traffic flow. Between Tuesday and Thursday, the differences are smaller and in most cases not significant. On some locations, there are however significant differences between Tuesday and Thursday, in particular concerning the ratio between the A.M peak and off-peak traffic flow. The results correspond to the results of the studies of Schmidt and Rakha & Van Aerde in the sense that Monday and Friday flows differ from core weekdays flow. In contradiction to the study of Stathopoulos & Karlaftis, traffic flows can be assumed to be Normally distributed in this study.

The route chosen is not representative for all urban traffic. Since all analysed traffic flows, including the traffic to and from the city centre show similar results, it can however be assumed that most urban traffic flows show comparable daily traffic profiles.

The results from this study have implications for urban traffic management. Firstly, the adjustment of signal settings on the basis of the day of the week possibly reduces travel times. Since the traffic on Monday and Friday differs from the traffic on Tuesday and Thursday it might be advisable to adjust the signal settings on these days. Secondly, also other urban traffic management measures -for example Variable Message Signs and access control- can be adjusted on basis of the day of the week. Finally, the obtained insight into differences in daily flow profiles across weekdays and their causes, offers opportunities for travel demand management.

With regard to the estimation of AADT, caution has to be taken when counting traffic for less then 24 hours. When traffic is counted during a morning peak, other adjustment factors have to be used then when traffic is counted during an off-peak period or during an evening peak. Furthermore, when one wants to estimate the amount of peak traffic on the basis of the average daily traffic, the day of the week has to be taken into account

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