

# TRAFFIC FLOW VARIATIONS IN URBAN AREAS

**J SAMPSON**

TTT Africa, Box 1109, SUNNINGHILL 2157  
Tel: 083 307-4666; Email: sampsonj@ttafrica.co.za

## ABSTRACT

At the 1983 Annual Transport Convention (ATC, now called SATC), the author presented a paper with the same title as the one above. The paper provided typical hourly, daily, weekly and annual traffic count patterns in urban areas.

Over the following 34 years the author has maintained records of traffic counts taken and has monitored and compared the typical variations with those produced in the original paper. It would appear from these that the underlying traffic flow patterns have remained much the same.

In this paper the opportunity has been taken to completely revise and update the 1983 figures using a selection of urban freeway and arterial locations from the 2015 SANRAL Comprehensive Traffic Observations (CTO).

## 1. INTRODUCTION

See Abstract.

## 2. DEFINITIONS

**Average Annual Daily Traffic (AADT)** is the total traffic volume in a year, including school and public holidays and weekends, divided by 365.

**Average Week Day Traffic (AWDT)** is the total traffic from Monday to Friday, in a week without school or public holidays, divided by five.

**Average Daily Traffic (ADT)** is the 24-hour traffic count taken on any typical working weekday in an urban area.

ADT is a good approximation of AWDT in an urban area.

As weekends and holidays are excluded, both ADT and AWDT are greater than AADT and should be used in preference to AADT when doing urban traffic studies.

**Traffic**, broadly defined, consists of light vehicles, heavy vehicles, buses, motorcycles, bicycles, pedestrians and any other forms of conveyance. Commonly however, the word traffic is used to refer to vehicles only, e.g. average daily traffic. If motorcycles and non-motorized traffic volumes are available, these should be specified separately and not included in ADT.

### 3. SOURCE DATA

The original 1983 paper **Traffic Flow Variations in Urban Areas** used traffic counts taken over a period of six years from 1976 to 1981 at the locations shown in Table 1. For ease of reference, these will be referred to as 1980 values in this paper.

The best available recent data comes from the Comprehensive Traffic Observations (CTO). SANRAL (Alan Robinson) is acknowledged for providing per lane classified traffic counts for every quarter of an hour for the entire year of 2015 at hundreds of sites in Gauteng.

From this data, the author selected sites thought to best represent typical urban conditions (Table 2). However, as all the sites measured by SANRAL are near the N1, N3, N4, N12, N14 or R21 “ring roads”, they therefore represent important feeder routes to the urban CBDs rather than the conditions in residential areas or the inner cities themselves. Nevertheless, there was one location common to both studies; the 1980 site 2 and the 2015 site 3.

**Table 1: The Traffic Count Locations used in the “1980” Study**

Site	Lanes	Days	AWDT	Location	Where in Johannesburg
1	4	6 yrs	107 100	M2 at Rosettenville Road	CBD
2	4	6 yrs	54 900	M1 south of Xavier St	Ormonde
3	~ 30	3*13hr	553 000	Inner cordon around Jhb CBD	CBD boundary
4	~ 36	3*13hr	713 000	Outer cordon municipal boundary	Old Jhb
5		7 day		Selected secondary stations	Major roads

**Table 2: The Traffic Count Locations used in this “2015” Study**

Site	Lanes	Days	AWDT	Location	Suburb	City
1	8	365	160 742	M1 N of Marlboro, S of Woodmead	Gallo Manor	Sandton
2	8	346	105 798	M2 E of Cleveland, W of N3	Cleveland	Johannesburg
3	8	281	127 754	M1 S of Xavier St, N of N12	Ormonde	Johannesburg
4	7/4	365	83 169	N14 S of Jean Ave, N of N1	Bromberrik	Centurion
5	6	356	42 107	R25 Modderfontein	Greenstone	Modderfontein

				Rd N van Riebeeek		
6	6	337	48 143	M18 Ontdekkers Road over N1	Maraisburg	Roodepoort
7	4	355	28 821	M6 Lynnwood Rd E of Rodericks	Lynnwood	Pretoria
8	4	352	27 405	M57 Kraft Rd E of N12, W of Barbara	Marlands	Germiston
9	2	365	17 205	M32 Pomona Road E of R21, W of R23	Pomona	Kempton Park
10	2	365	22 233	R101 Lavender Rd N of Lindeveldt	Onderstepoort	Pretoria North
11	4	365	24 672	N1 N of Murrayhill, Pta - Polokwane	rural	rural

#### 4. DAILY TRAFFIC VOLUMES

This Chapter deals with variations in traffic on a day to day basis throughout the year. Chapter 5 deals with hourly variations throughout the day.

##### 4.1 AADT versus AWDT

In the definitions, it was mentioned that AWDT is higher than AADT. The difference is shown in Table 3.

**Table 3: The percentage of Average Week Day Traffic to Average Annual Daily Traffic**

	AWDT / AADT	AADT / AWDT
1980	114.5	87.3
2015	116.3	86.0

##### 4.2 Typical ADT volumes

The typical daily two-way volumes that can be expected on different Classes of Roads are listed in Table 4. These are based on a combination of the 1983 findings and the 2012 TRH26 **South African Road Classification and Access Management Manual**.

**Table 4: Typical Daily Volumes on Class 1 to 5 Roads**

	Class 1 freeway	Class 2 major arterial	Class 3 minor arterial	Class 4a major collector	Class 4b minor collector	Class 5 local street
minimum	40 000	15 000	10 000	2 000	1 000	0
maximum	230 000	60 000	40 000	25 000	10 000	2 000

The busiest road in the country is thought to be the Johannesburg - Pretoria N1 freeway between the Buccleuch and the Allandale interchanges, which carries 230 000 vehicles per day (2016).

### 4.3 Annual Variation in Daily Traffic

The variation in daily traffic throughout the year is shown in Figure 1. The daily volume on weekends, the Christmas and Easter holidays, and public holidays are clearly lower, but if those were to be removed, typical week days are concentrated closely around the mean AWDT. The tendency of traffic to build up from Monday to Friday can also be seen.

### 4.4 Monthly Variation

The variation in 2015 daily volumes (Monday to Sunday) for all ten urban locations (Table 2) aggregated into months is shown in Table 5 and compared with the 1980 findings. In both studies, February / March and October / November are busier than average.

**Table 5: Variation in monthly volume as a percentage of AADT**

<b>Month</b>	<b>Jan</b>	<b>Feb</b>	<b>Mar</b>	<b>Apr</b>	<b>May</b>	<b>Jun</b>	<b>Jul</b>	<b>Aug</b>	<b>Sep</b>	<b>Oct</b>	<b>Nov</b>	<b>Dec</b>
1980	99	107	102	101	100	96	97	96	99	104	106	95
2015	91	104	105	97	100	100	104	101	103	103	104	87



## 4.5 Week of the year

The average Monday to Friday volumes, including those weeks with public and school holidays, as a percentage of AWDT are shown in Table 6 for 2015 (not done in 1980). Weeks with a public holiday are coloured orange and school holidays with no public holiday in that week in yellow. There are 35 weeks unaffected by holiday days and 17 weeks with holidays. Higher weeks (those 2% or more above average) are shaded light green.

It is interesting that school holidays only have a small effect on weekly volumes but a public holiday, which in most cases is on only one day of a five-day week, has a significant effect on the weekly average.

For weeks unaffected by holidays, there is little variation in AWDT with no week being more than 3% above or below the average.

**Table 6: Variation in weekly volume as a percentage of AWDT**

wk	1	2	3	4	5	6	7	8	9	10	11	12	13
2015	79	94	97	98	98	100	100	102	102	102	101	101	90

wk	14	15	16	17	18	19	20	21	22	23	24	25	26
2015	88	100	99	81	101	98	98	100	99	98	87	99	99

wk	27	28	29	30	31	32	33	34	35	36	37	38	39
2015	97	97	98	101	102	90	99	101	101	101	101	90	103

wk	40	41	42	43	44	45	46	47	48	49	50	51	52
2015	100	99	99	102	101	100	99	101	103	99	85	64	48

## 4.6 Day of the week variation

In Table 7 the daily flows are listed as a percentage of AWDT. The consistency between the data sets, although they are 35 years apart, is remarkable.

**Table 7: Variation in day of the week volumes as a percentage of AWDT**

day	Mon	Tue	Wed	Thu	Fri	Sat	Sun
1980	97.2	98.2	99.9	99.6	105.2	73.2	53.3
2015	97.0	98.1	99.3	100.0	105.6	72.0	53.7

The increased volume on a Friday is probably due mainly to shopping, but also pub, restaurant, entertainment, sport, recreational and weekend getaway traffic.

For practical purposes, traffic volume counts are done on any day of a typical week, including Fridays. While Table 7 (and Figure 1) indicates that the daily traffic on a Friday is consistently higher than average, the same was not found for the peak periods. The

difference between doing a count on a Friday compared to other weekdays is explored in more detail in Chapter 5, Table 12.

## 5. HOURLY TRAFFIC VOLUMES

The volume of traffic on roads varies greatly in a typical 24-hour day. It also varies per direction, particularly in peak periods.

Where directional traffic is mentioned below, in each case “in” is towards the city centres and “out” is away, regardless of the actual volumes.

### 5.1 Hourly Traffic Variation

Figures 2 and 3 are from the 1983 paper and represent the typical hourly variation during an average day at a suburban (s) and CBD (c) location respectively.

Figure 4 is the average hourly variation at the ten urban locations studied in 2015. The peak hour volumes, which occur somewhere between 5:30 and 8:00 in the morning and between 15:15 and 17:45 in the evenings at the different locations (Table 9), have been standardised at 6:30 to 7:30 and 16:30 to 17:30 when taking the averages for the purposes of Figure 4.

The hourly volumes in the figures are provided in Table 8 for ease of comparison.

**Table 8: Hourly Variation as a Percentage of ADT**

hr begin	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00
1980s	0.6	0.4	0.3	0.4	0.5	1.6	6.1	9.9	7.3	5.5	5.1	5.0
1980c	0.4	0.2	0.0	0.1	0.5	1.3	4.9	8.7	7.8	6.4	6.4	6.4
2015	0.3	0.2	0.2	0.2	0.5	2.3	7.1	8.2	6.7	5.9	5.8	5.9
hr begin	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
1980s	5.1	5.3	5.6	6.1	8.7	9.0	6.2	4.0	2.7	1.9	1.7	1.2
1980c	6.4	6.3	6.7	7.3	9.5	7.9	4.9	3.1	1.9	1.3	1.2	0.8
2015	6.1	6.3	6.5	7.1	8.2	7.7	5.6	3.5	2.4	1.6	1.1	0.7

In the original paper, it was noted that the morning peak hour was higher but of a shorter duration than the afternoon peak hour. In suburban areas, both the AM and PM “two-way” peaks were about 10% of the ADT and the off-peak about 5.2% of ADT. For the CBD areas, the peaks were noticeably lower at around 9% of ADT while off-peak volumes were higher at 6.4% of ADT.

It was expected that much the same “suburban” pattern would be found in 2015 but this was not the case. The two-way peak volumes are much lower at 8.4% of ADT and average off-peak volumes are higher at 6.0%, plus increase noticeably from 5% to 7% of

ADT during the day. The peak periods started earlier (at 6:30 on average, but at 5:30 on some roads, as opposed to 7:00 in 1980). The peaks were also flatter and of a slightly longer duration.

Part of this difference between 1980 and 2015 is probably due to the “ring road” location of the counts and the capacity conditions of the freeways feeding the highways measured. This in turn leads to peak spreading as well as people leaving earlier for work. To compensate for the early arrival times, people start returning home earlier too, with the afternoon volumes leading up to the peak much higher than before.



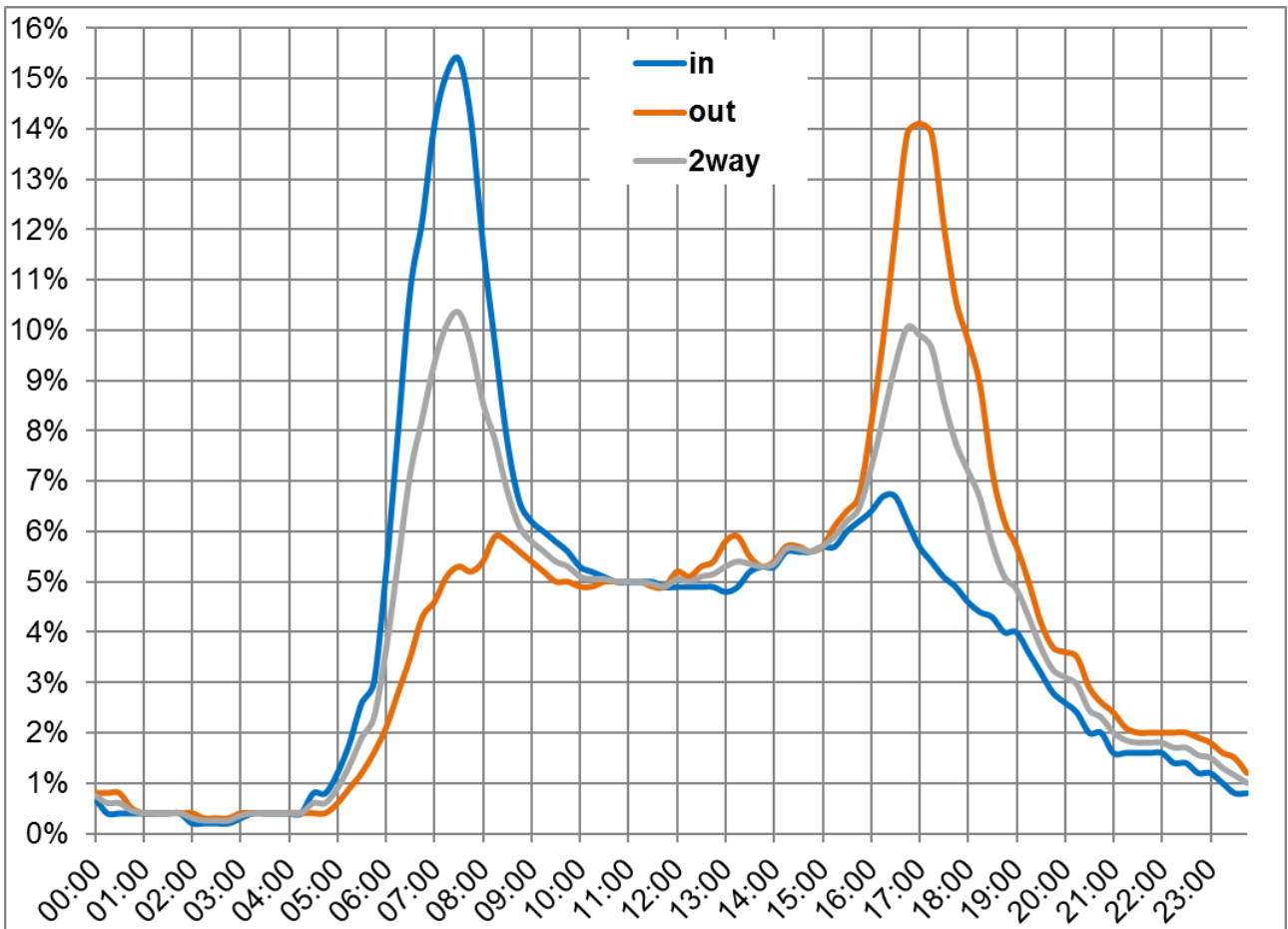


Figure 2: Hourly Variation as a % of ADT in a Suburban Area (1980)

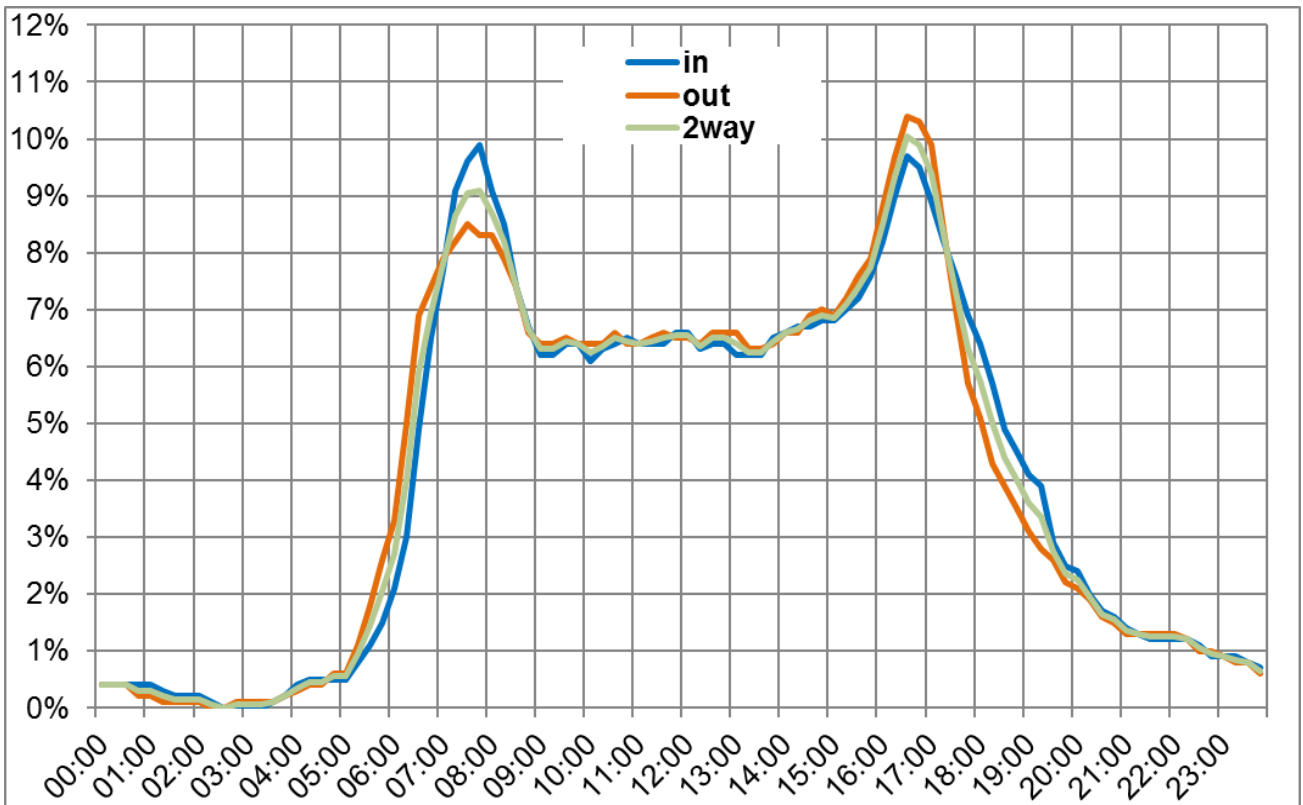
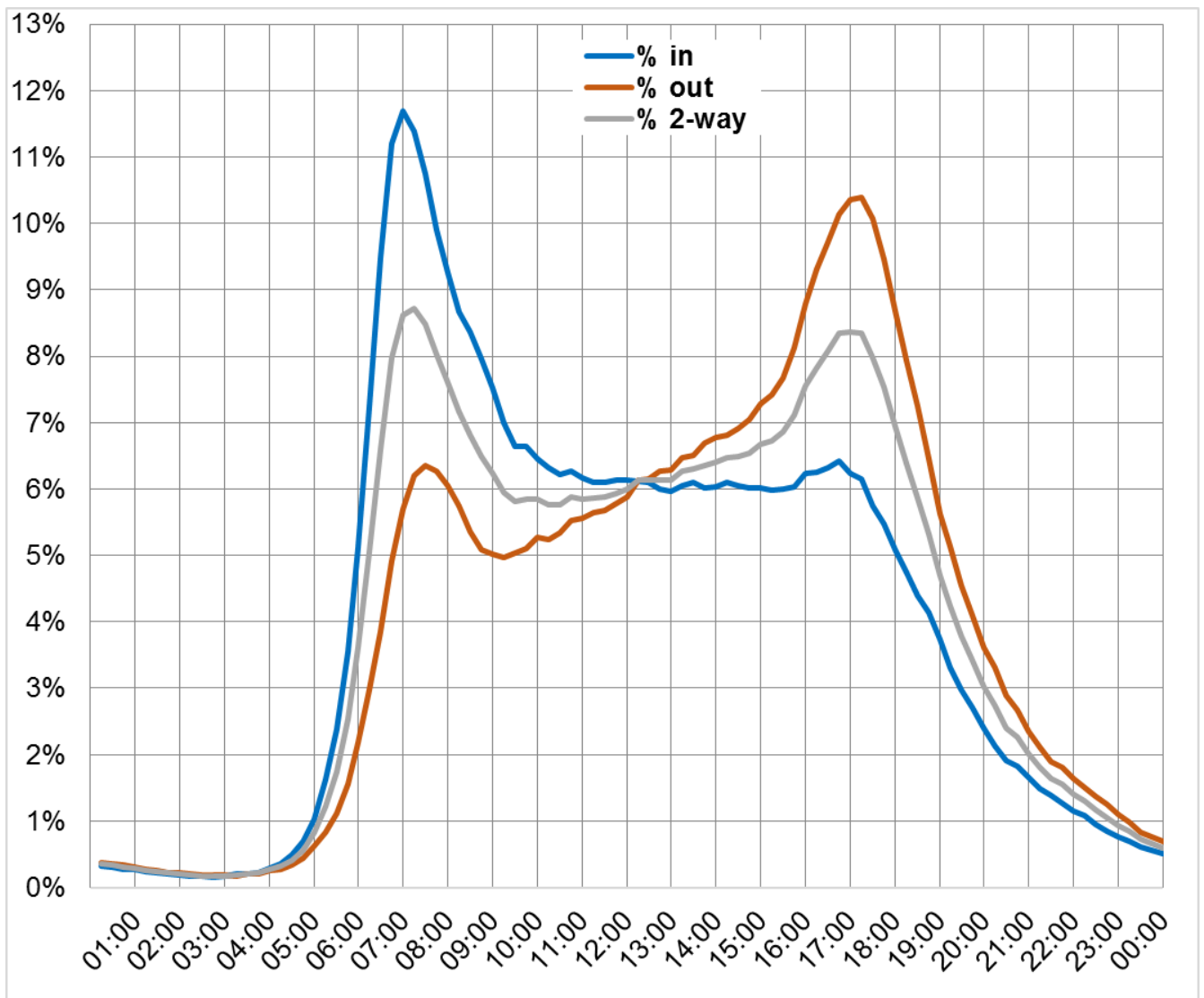


Figure 3: Hourly Variation as a % of ADT in the CBD (1980)



**Figure 4: Hourly Variation as a % of ADT on major roads (2015)**

Another part of the difference would be due to the different peak hour start and end times as well as different peaking characteristics across the ten sites. An indication of these differences is given in Table 9 where the start times of the peak periods and the percentage of inbound traffic volume in the morning and outbound traffic volume in the evening as well as the two-way traffic is given.

Based on the above findings, the 2015 morning peak hour starts between 6:30 and 6:45, and ends between 7:30 and 7:45 (twenty minutes earlier than in 1980), with 11.9% (standard deviation 2.3%) of the inbound traffic and 8.9% (standard deviation 1.1%) of the two-way traffic occurring during that hour.

The peak in 2015 outbound traffic is from 16:15 / 16:30 to 17:15 / 17:30 (ten minutes earlier than in 1980) with 11.0% (standard deviation 1.8%) of the daily traffic heading homewards and 8.7% (standard deviation 0.8%) of the two-way traffic during the hour.

Off peak volumes (9:00 to 15:00, but 10:00 to 14:00 is more consistent) can be taken as 6.0% of ADT (standard deviation 0.6%).

**Table 9: Inbound and Outbound Peaks as Percentage of AWDT**

site	1980 sub	1980 cbd	1	2	3	4	5	6	7	8	9	10
<b>In start</b>	7:00	7:15	6:15	7:00	5:30	6:45	6:15	6:15	6:45	6:30	6:45	6:00
<b>In %</b>	14.7	9.4	9.7	10.9	11.5	8.5	12.7	15.4	10.1	10.5	11.4	9.3
<b>2way %</b>	9.9	8.9	7.7	8.3	6.8	8.1	8.3	10.1	8.0	10.2	9.3	7.3
<b>Out start</b>	16:30	16:15	15:15	16:15	16:45	16:30	16:45	16:00	16:00	16:45	16:30	16:45
<b>out %</b>	13.5	10.1	8.6	9.7	11.6	8.7	11.0	11.4	10.7	10.9	9.4	8.9
<b>2way %</b>	9.6	9.7	7.3	7.5	8.5	8.3	8.4	8.3	8.6	9.6	8.2	7.7

## 5.2 Estimating ADT from hourly counts

Generally, when traffic studies are done, manual counts of turning movements are undertaken from 6:00 to 9:00, 10:00 or 11:00 to 14:00, and 15:00 and 18:00. This study confirms that these are the most suitable periods to obtain the morning peak, off peak and evening peak volumes.

It is however useful to know the ADT as this single figure gives a good indication of the overall use of the intersection as well as a check on whether any specific hour count looks reasonable.

In order of accuracy, one of the following three methods of estimating ADT is suggested:

- i. If a 12-hour count is available, the study shows that 81.5% of the daily traffic occurs during the hours of 6:00 to 18:00 (82.6% in the 1983 study). The 12-hour count divided by 0.82 gives a good estimate of ADT.
- ii. During 6:00 to 9:00, 22.0% of the ADT typically occurs, and between 15:00 and 18:00, 22.9% occurs. An average off peak hour is 6.0% of ADT. To estimate ADT from these counts therefore it is recommended that the 6:00 to 9:00 total be divided by 0.22, the 15:00 to 18:00 total be divided by 0.23, and the 10:00 to 14:00 average hour be divided by 0.06. The average of these three values gives the ADT.
- iii. Alternatively, the AM peak hour is multiplied by 3.75, the PM peak hour by 3.85 and the off-peak hour by 5.55 and the three results are added. The formulation gives approximately equal weight to each period counted as  $8.9\% \times 3.75 = 33\%$ ,  $6.0\% \times 5.55 = 33\%$  and  $8.7\% \times 3.85 = 34\%$ , the total being 100%.

### 5.3 Peak hour factor

The peak hour factor (PHF) is the peak hour volume divided by four times the highest quarter hour volume. A higher factor indicates the traffic is evenly spread throughout the hour and is a sign that capacity has been reached. In Table 10 the 1980 PHF values are compared to 2015.

Again, the indication is that peak hour congestion has increased, particularly on Class 2 and 3 arterial roads.

**Table 10: Peak Hour Factors on various Road Classes**

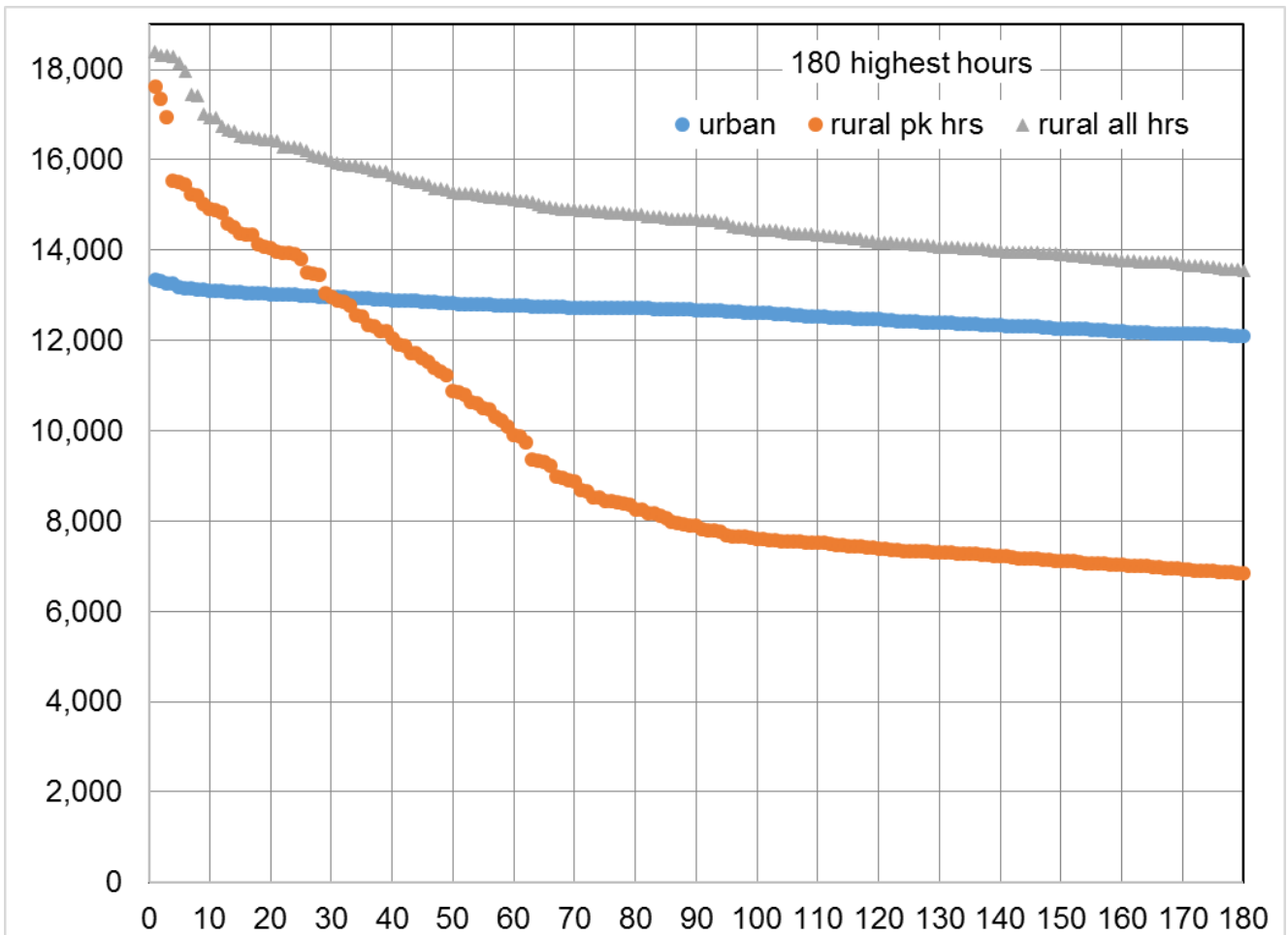
	<b>Class 1 freeway</b>	<b>Class 2 major arterial</b>	<b>Class 3 minor arterial</b>	<b>Class 4a major collector</b>	<b>Class 4b minor collector</b>	<b>Class 5 local street</b>
1980	0.98	0.96	0.92	0.90	0.85	0.80
2015	0.98	0.975	0.97			

### 5.4 30<sup>th</sup> Highest Hour

In rural areas, the concept of the 30<sup>th</sup> highest hour is often used for the design volume. The theory is that volumes higher than the 30<sup>th</sup> highest are unusual and that it would be wasteful to design for values that occur infrequently.

In this section, a rural road (N1 north of Murrayhill interchange between Pretoria and Polokwane, Site 11) is compared to an urban road (M1 Sandton, Site 1). The 180 highest urban hours are compared with the same “morning and evening peak” times on the rural road (Figure 5 blue and orange lines). Note that the volumes on the rural road have been substantially increased to equalize the 30th highest urban hour so that a direct comparison can be made.

For interest, the actual 180 highest hours in the full year for the rural road are shown in grey.



**Figure 5: Comparison of the 180 Highest Hours in Urban and Rural Areas**

The maximums, minimums, means and 30<sup>th</sup> highest hour volumes corresponding to urban peak hours are compared in Table 11.

**Table 11: Comparison of Urban and Rural Highest Hours**

urban	veh/hr	diff from mean	rural	adjusted veh/hr	diff from mean
max	13 338	5.6%	max	17 613	87.0%
30th	12 967	2.7%	30th	12 967	37.7%
mean	12 629		mean	9 418	
min	12 097	- 4.4%	min	6 844	- 37.6%

It can clearly be seen that in the urban area it makes little difference which of the 180 highest hours is used for design, but in the rural area there is a big difference in the “equivalent peak time” volumes.

In conclusion, the 30<sup>th</sup> highest hour is a meaningless concept in an urban area.

## 5.5 Hourly Variation by Day of the Week

The variation in daily volume on different days of the week was noted earlier. In this section the peak hour volumes on a Monday to Friday have been compared to the average peak hour volume. One hundred and eighty peak hours at each of the ten sites were averaged.

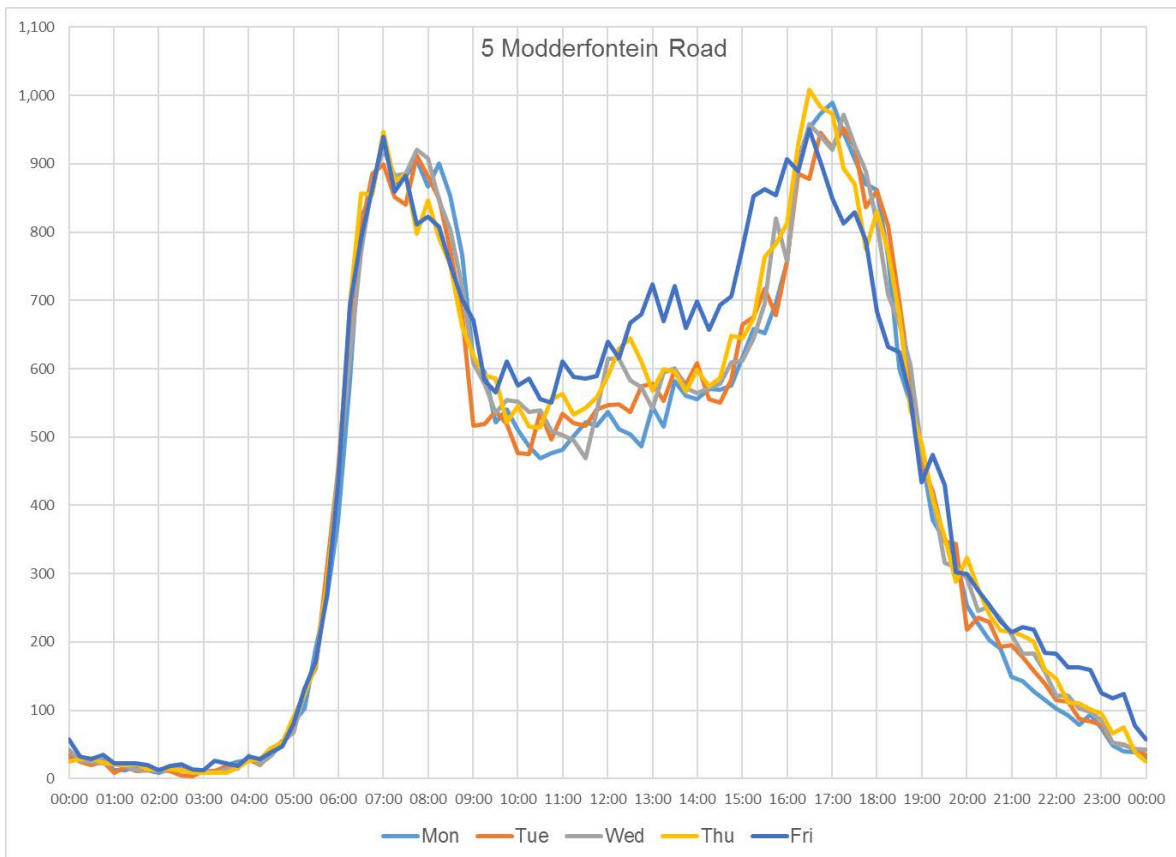
**Table 12: Percentage Variation in Hourly Peak Volumes on Different Week Days**

day	Mon	Tue	Wed	Thu	Fri
am peak	100.3	99.9	100.7	99.9	99.1
pm peak	98.7	100.2	99.8	101.8	99.4

When daily traffic volumes are considered, a Friday is consistently higher at 105% (Table 7) compared to the other week days. However, when peak hour volumes are measured (Table 12), a Friday is slightly lower but effectively the same as any other day. This is probably because capacity is reached during peaks every day of the week.

In Figure 6 below, the actual quarter hour volumes have been averaged over several weeks on Modderfontein Road (site 5, chosen as the closest to “average” site). The higher volumes on a Friday occur during the period between 10:00 and 16:00 and maybe are not caused by additional shopping or recreational traffic as surmised earlier?

It can be concluded nevertheless that when urban traffic studies are done for peak traffic impact or traffic control device studies, unless there is a specific reason to suspect otherwise, it is unlikely to make a difference on which day of a normal week the traffic counts are taken.



**Figure 6: Traffic Volumes by Day of Week**

## 6. HEAVY VEHICLES

The percentage of heavy vehicles (HV) on a road section can vary from 0% to almost 100%, so cannot be accurately generalized.

It is thought however, that heavy vehicles tend to avoid the peak hours. To test this theory, a random sample of heavy vehicle usage of the M1 in Sandton was taken. It was found that on a lane where the average HV usage was 6.5%, this regularly exceeded 10% and even 20% in the hours from 9:00 to 16:00 and 0:00 to 5:00 while dropping to between 2% and 4% during peak periods, thus appearing to confirm the theory, even if the additional light vehicle volumes during peak hours are discounted.

If an estimate of HV must be made, it is suggested that heavy vehicles and buses be taken at 3% in peaks and 7% off-peak.

Table 13 provides the average usage of heavy vehicles on the different road classes measured in this study.

**Table 13: Mix of heavy vehicles by Road Class (2015)**

	<b>Class 1 freeway</b>	<b>Class 2 major arterial</b>	<b>Class 3 minor arterial</b>
% Heavy Vehicles	6.5%	4.5%	9.8%
<i>consisting of:</i>			
<i>% short HV</i>	<i>58%</i>	<i>64%</i>	<i>67%</i>
<i>% medium HV</i>	<i>21%</i>	<i>21%</i>	<i>17%</i>
<i>% long HV</i>	<i>21%</i>	<i>16%</i>	<i>16%</i>

## 7. LANE UTILIZATION

The lane utilization is listed as the percentage of vehicles in each freeway or arterial lane starting with the slow (outside) lane to the fast (inside) lane. In all cases, the slow lane tends to be avoided.

It can also be noted that trucks use the slow lane more than light vehicles, but anecdotally it seems to this author that many more trucks use the faster lanes than in years gone past.

**Table 14: Lane Usage on Multi-Lane Roads**

<b>lanes per direction</b>	<b>2 lanes</b>	<b>3 lanes</b>	<b>4 lanes</b>
1980 all	36 : 64	22 : 35 : 43	16 : 30 : 30 : 24
2015 all	46 : 54	25 : 42 : 33	19 : 27 : 30 : 24
<i>2015 HV only</i>	<i>70 : 30</i>	<i>37 : 45 : 18</i>	<i>25 : 42 : 24 : 9</i>

## **8. CONCLUSION**

Many of the traffic count variations found in the 1980 study have been confirmed. The biggest change is that the peak periods occur sooner, last longer and are not as “peaky”. All three of these observations can be ascribed to increasing congestion where motorists avoid the peak hours where possible by leaving earlier (or later) and where capacity restraints limit the volume of traffic and spread it over a longer period.

Given the generally predictability and regularity of the traffic volumes in urban areas, as confirmed in this study, the factors derived can be used with confidence.