GAUTENG CONGESTION STRATEGY HEAVY VEHICLE RESTRICTIONS ON FREEWAYS

Markman, M.[1], Steynberg, M.[2] and van As, C.[3]

[1]Arup Transportation
[2]Gauteng Department of Public Transport, Roads and Works
[3]Traffic Engineer

ABSTRACT

An efficient transportation system is a critical element for sustainable economic development. The present high level of congestion on large portions of the Gauteng road network is therefore a major cause for concern. It leads to a loss in productivity owing to longer travel times and increased fuel consumption, restricts regional accessibility and the exposure of workers to job opportunities. It also results in urban sprawl as business relocates away from congested areas. It further causes increases in air pollution and the general lowering of quality of life.

The Gauteng Department of Public Transport, Roads and Works ("Gautrans") are considering various measures to combat traffic congestion on roads in Gauteng. One of the proposed measures is the imposition of restrictions on heavy vehicles on freeways. These restrictions include the limiting of heavy vehicles to the "slow" lane and the total ban of such vehicles during peak periods from the freeway.

A major experiment was undertaken on the impacts of the heavy vehicle restrictions on traffic congestion on the freeway system. At the time of the writing of the report, the first phase of the project was completed, namely the imposition of the "keep left" restriction. The aim of the paper is to present the findings of this phase of the study.

1. INTRODUCTION

Traffic congestion in Gauteng has become a serious problem, and is seriously affecting transportation in the province.

The following is a brief description of the situation in the province:

- Traffic volumes (demand) are increasing on Gauteng roads and it is estimated that these volumes will double over the next decade.
- The provision of road capacity (supply) is not keeping pace with demand.
- It is estimated that 23% of Gauteng's roads suffer from congestion during peak hours.
- There is some indication that traffic operations are affected by poor driver discipline, unroadworthy vehicles, heavy vehicles travelling slowly and slow vehicles not keeping to the left lane
- Traffic operations are often significantly impacted by incidents such as accidents causing congestion (for example overturned trucks can block an entire carriageway).
- It has been estimated that the present cost of congestion on all provincial and national roads in Gauteng is R1.5 billion per annum.

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A workshop on congestion was hosted by the Gauteng MEC for Transport and Public Works (Gautrans) in Gauteng on 27 October 2000. The following broad strategies for alleviating congestion were identified during the workshop:

- Land-use related measures and policies
- Supply side and operational issues
- Measures relating to transport demand management.

Land-use related measures and policies include inter alia, densification and corridor development, revitalising of central business districts and the protection and enforcement of land-use plans. Supply side and operational issues include a wide spectrum of infrastructure upgrading, expansion and management aspects. Transport demand management (TDM) include a variety of elements, such as public transport, restricting or prohibiting access and charging for access and parking.

2. THE HEAVY VEHICLE RESTRICTION PROJECT

A variety of congestion alleviation measures have been identified by the Gauteng Department of Public Transport, Roads and Works ("Gautrans"). The imposition of heavy vehicle restrictions on freeways is one of these measures.

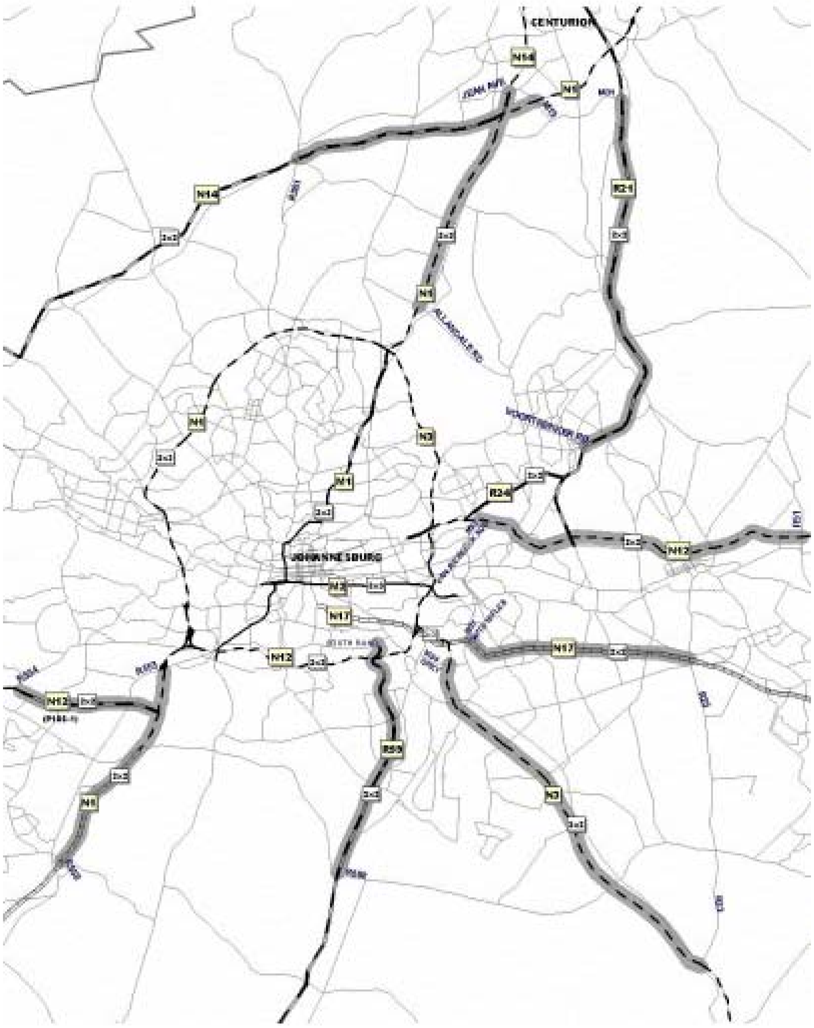

Figure 1. Freeways on which heavy vehicle restrictions were introduced.

The measure involves the following:

- Restriction of heavy vehicles to the left lane during peak hours.
- Introduction of minimum speed limits (all vehicles).
- Prohibiting heavy vehicles on freeways during peak periods.

Gautrans decided to implement the above measures as a pilot project. The first two measures were implemented during the first phase of the pilot project, while the third measure will be implemented during the second phase of the pilot project. At the time of writing this paper, the final decision still has to be made whether or not to proceed with the third measure (second phase).

The first phase of the pilot study was undertaken on a number of freeways in Gauteng, shown in Figure 1. It was initially limited to the R59 freeway to the south of Johannesburg and was introduced gradually to allow drivers time to adjust to the measures. A large traffic police presence was maintained during the initial stages of the project. The pilot study was then extended to the other freeways around Johannesburg.

High visibility road signs were erected on the freeways at regular intervals. These signs included prohibition of heavy vehicles from all lanes except the left lane during the morning and afternoon peak periods and the posting of a minimum 60 km/h speed limit sign applicable to all vehicles throughout the day.

3. LAW ENFORCEMENT

During the planning of the project, it was realised that a high level of law enforcement would be required to ensure that heavy vehicle drivers would comply with the restrictions. Excellent co-operation was obtained from the provincial traffic department during the project.

A high level of visibility and law enforcement was maintained along the freeways, particularly during the initial stages of the project. Drivers were initially warned and subsequently given fines because of non-compliance with the restrictions.

In spite of the high level of law enforcement, it was very difficult to obtain the co-operation of heavy vehicle drivers. Both the "keep left" restriction and the "minimum speed limit" were ignored or not complied to. This sometimes even happened in the direct presence of traffic officers.

4. TRAFFIC OBSERVATIONS

Traffic observations were made at various locations on the freeways. Some manual observations were made, but the more important observations were made using electronic loggers. The equipment allowed for the measurement of the speed of individual vehicles, as well as classifying vehicles as heavy or light. At some locations, axle counters were used to improve the classification accuracy.

The amount of information collected was staggering. A total of approximately 900 Mbytes of data were collected on all the freeways. The analysis of the data was undertaken by means of special software developed during the project. The verification of the data was also found to be a difficult and time-consuming process, in spite of specialised commercial software available for this purpose.
It is not possible to include all the findings of the study in this paper due to restricted space, and only a summary of the more pertinent results is therefore given. Table 1 shows some of the more important findings at a number of selected locations.

TABLE 1. SUMMARY OF BEFORE AND AFTER FINDINGS AT SELECTED LOCATIONS.									
Location of observation station	**Before / After**	**AM Peak period (7-9 a.m.)**				**PM Peak period (4-6 p.m.)**			
		% Heavy	**% Heavy in left lane**	**Avg light vehicle speed**	**Level of service**	**% Heavy**	**% Heavy in left lane**	**Avg light vehicle speed**	**Level of service**
N1 Freeway at Jean Avenue Northbound to Pretoria	Before After	2.5 2.4	**50.4** **59.8**	100.0 99.8	D.27 D.29	2.1 2.1	**50.0** **54.9**	**84.8** **93.0**	F E.94
N1 Freeway at Jean Avenue Southbound to Johannesburg	Before After	2.3 2.2	49.1 48.9	**102.4** **92.8**	**D.89** **E.21**	3.0 2.8	**49.7** **57.6**	106.4 104.9	C.85 C.91
N1 Freeway at Old Johannesburg Rd Northbound to Pretoria	Before After	4.0 3.8	81.5 80.7	112.3 111.3	C.38 C.39	1.8 1.9	**73.4** **78.1**	97.1 96.0	E.78 E.76
N1 Freeway at Old Johannesburg Rd Southbound to Johannesburg	Before After	4.0 4.5	83.0 83.4	116.5 115.3	C.23 C.34	1.9 1.9	80.7 82.7	**101.1** **90.5**	F F
N1 Freeway at Summit Rd Northbound to Pretoria	Before After	4.1 4.0	**72.2** **78.6**	114.7 113.0	C.26 C.38	1.9 1.9	**71.7** **78.0**	**94.9** **80.6**	F F
N1 Freeway at Summit Rd Southbound to Johannesburg	Before After	3.2 3.0	61.6 60.7	**109.1** **100.4**	F F	5.7 5.5	**68.7** **75.6**	124.3 122.8	C.68 C.74
N1 Freeway at New Road Northbound to Pretoria	Before After	4.8 4.7	84.3 88.1	118.0 116.5	C.21 C.34	2.8 2.6	85.3 87.4	74.8 71.9	F F
N1 Freeway at New Road Southbound to Johannesburg	Before After	3.7 3.2	**75.2** **81.4**	**54.7** **64.7**	F F	5.9 5.5	**69.5** **78.7**	107.9 108.3	C.83 C.86
N12 East, Near R21 interchange Eastbound to Witbank	Before After	7.2 7.4	**62.9** **71.0**	112.9 112.1	B.07 B.07	3.3 3.4	**54.7** **62.5**	94.0 93.3	D.56 D.45
N12 East, Near R21 interchange Westbound to Johannesburg	Before After	3.2 3.6	**70.8** **74.8**	**92.5** **98.5**	D.36 D.25	7.4 8.0	**58.8** **69.1**	110.4 108.5	B.20 B.28
N3 Freeway, South of Johannesburg Northbound to Johannesburg	Before After	11.1 11.6	**57.8** **62.1**	101.7 100.8	C.28 C.31	9.3 9.3	63.1 65.4	105.4 105.4	A.98 B.01
N3 Freeway, South of Johannesburg Southbound to Durban	Before After	6.6 8.3	**57.3** **77.2**	112.8 111.8	A.83 A.82	9.0 8.9	**61.3** **65.9**	108.3 107.2	C.04 C05
R59 Freeway, South of Johannesburg Northbound to Johannesburg	Before After	5.4 5.4	**80.4** **89.5**	120.7 117.3	C.41 C.43	6.4 5.9	84.5 87.2	128.3 124.0	B.34 B.40
R59 Freeway, South of Johannesburg Southbound to Van Der Bijl Park	Before After	5.7 5.3	**88.2** **94.6**	**129.8** **135.0**	B.53 B.51	5.0 4.8	**81.8** **90.3**	**124.9** **133.5**	D.14 D.07
R21, North of Olifantsfontein Northbound to Pretoria	Before After	11.3 6.9	88.8 88.6	108.6 109.6	C.42 C.12	6.0 5.1	91.8 88.8	106.0 105.8	C.85 C.86
R21, North of Olifantsfontein Southbound to Kempton Park	Before After	4.5 4.7	94.1 92.4	100.2 102.3	B.01 C.70	9.3 9.6	87.1 87.7	102.3 103.0	C.61 C62
R21, South of Olifantsfontein Northbound to Pretoria	Before After	6.9 6.0	89.0 91.0	111.0 109.3	B.80 B.66	3.0 3.6	**98.1** **94.3**	107.5 106.7	C.22 C.36
R21, South of Olifantsfontein Southbound to Kempton Park	Before After	3.5 3.6	**88.9** **95.6**	105.3 103.9	C.60 C.49	8.1 8.3	89.8 91.1	108.9 108.7	B.99 B.95

The following information is given:

- Location of observation station
- AM Peak and PM Peak periods (two hour each)
- Before/After - Observations before and after implementation of the restrictions
- % Heavy - Percentage of heavy vehicles on the road
- % Heavy in left lane - Percentage of heavy vehicles using the left lane
- Avg light vehicle speed - Average speed of light vehicles only (heavies excluded)
- Level of Service

The level of service (LOS) given in the table is based on the traffic density criterion, as defined by the Highway Capacity Manual (2000). The service levels are indicated by a letter followed by a number.

This number is a percentage indicating the depth within a level of service a road is operating. For example, a level of service C.38 indicates that the road is operating at a depth of 38% within LOS C.

The table shows that the restrictions had no or very little impact on traffic operations at some locations, while some impacts were observed at a number of locations. It is, however, not certain whether these are significant, or whether it is due to unstable flow conditions. Traffic operations improved at some of the locations, but deteriorated at other locations (all observations were undertaken on freeways).

The table also shows that heavy vehicles constitute a relatively small proportion of traffic (2% to 12%) during the peak periods. The before studies also indicate that on most freeways a relatively large proportion of heavy vehicles has already been using the left lane before the restrictions were introduced.

The restrictions did result in some increase in the utilisation of the left lane by heavy vehicles at about half the locations (shown bold), but had no or very little affect at the other locations due to non-compliance to the keep left restrictions. Because of this, the restrictions generally had little or no impact on the operational level of service during peak periods.

5. SPEED-FLOW RELATIONSHIPS

The data collected during the project also provided an opportunity to investigate speed-flow relationships at the locations where the data were collected (freeways). Examples of the relationships are shown in Figures 2 to 4 for different types of conditions. The speed-flow data shown in the figures were collected in 15-minute intervals.

The passenger car unit (pcu) speeds shown in the figures are not the speed of light vehicles, but represents the equivalent speed of a traffic stream in which heavy vehicles have been replaced by their passenger car equivalents. Replacing slower heavier vehicles by faster light vehicles has the effect that speeds are increased, but this increase is counteracted by the increase in the number of passenger car units (each heavy vehicle is replaced by more than one pcu).

The following equation was fitted by means of regression analysis to the speed-flow data:

$$V_O = f_V - \left(\frac{Q_O}{f_Q}\right)^2$$

with:

$$V_o = f_H \cdot V$$

$$Q_o = f_H \cdot Q$$

$$f_H = 1 + \frac{P_H}{100} \cdot (PCU - 1)$$

where:

V_O	Pcu speed (km/hour/lane)
V	Speed of mixed traffic stream (km/h)
Q_O	Pcu flow (veh/hour/lane)
Q	Traffic flow of mixed traffic stream (veh/hour/lane)
P_H	Percentage heavy vehicles in traffic stream
PCU	Passenger car equivalent of heavy vehicles
f_V	Free flow pcu speed (km/h)
f_Q	Flow factor
f_H	Heavy vehicle adjustment factor

The above equation differs from the one used by the Highway Capacity Manual (2000), but was found to provide a better fit to local data.

A very important and interesting derivation can be made from the above equation. The Highway Capacity Manual uses the traffic density of the pcu traffic stream as its criterion for establishing level of service. The following equation can be used to estimate traffic density (K) from pcu speed (V_O) and flow (Q_O), and also of from the speed V and flow Q of the mixed traffic stream:

$$K = \frac{Q_O}{V_O} = \frac{Q}{V}$$

The above equation indicates that the density of the pcu traffic stream is exactly equal to the density of the mixed traffic stream. The density of the pcu traffic stream is increased by the increase in number of passenger car units when heavy vehicles are replaced by pcu's, but the speed is also increased at the same time. These two increases counteracts each other, with the result that density is not affected by such transformation.

The above finding indicates that it is not necessary to convert the traffic stream to an equivalent pcu stream when establishing level of service based on traffic density. The level of service can be directly derived from traffic observations.

The PCU factors of heavy vehicles were found to be relatively low, varying typically between about 1,2 and 2,0. These values correspond to those given in the Highway Capacity Manual (2000), but are contrary to the general perception that heavy vehicles in South Africa have a greater impact on the flow of traffic compared to vehicles in the United States. The PCU values given in the manual for heavy vehicles vary between 1,5 and 2,5 for level to rolling terrain (4,5 for mountainous terrain).

The maximum flow observed during the project was about 2200 to 2300 pcu's per hour per lane. These flows occurred at pcu speeds of between 80 and 90 km/h. An important finding, however, was that these high flows were on roads with stable operating conditions. Figures 2 and 3 are example of freeways on which flows are relatively stable.

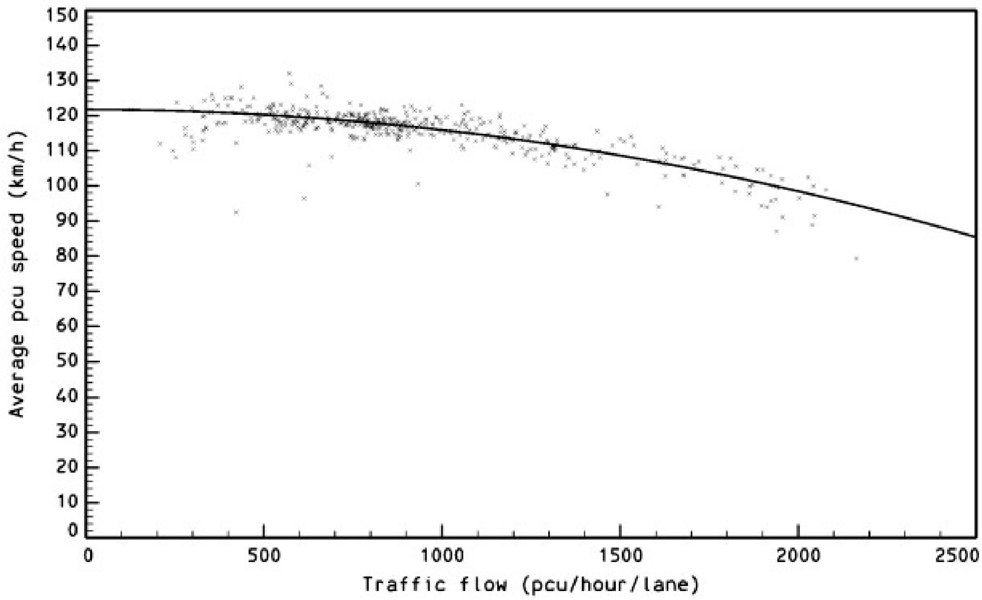

Figure 2. Example speed-flow relationship on a freeway with stable operating conditions (observations in 15-minute intervals).

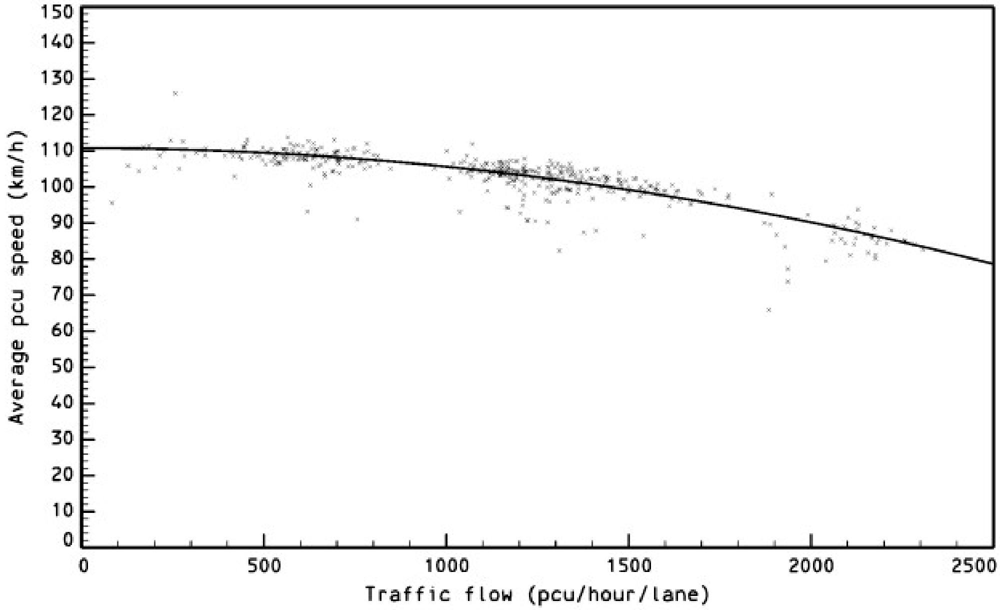

Figure 3. Example speed-flow relationship on a freeway with stable operating conditions (observations in 15-minute intervals).

Figure 4 shows the speed-flow relationship for a freeway on which flows are unstable and where flow is affected by congested interchanges as well as steep gradients. The maximum flows on such roads were found to be significantly lower than on roads with stable flow conditions.

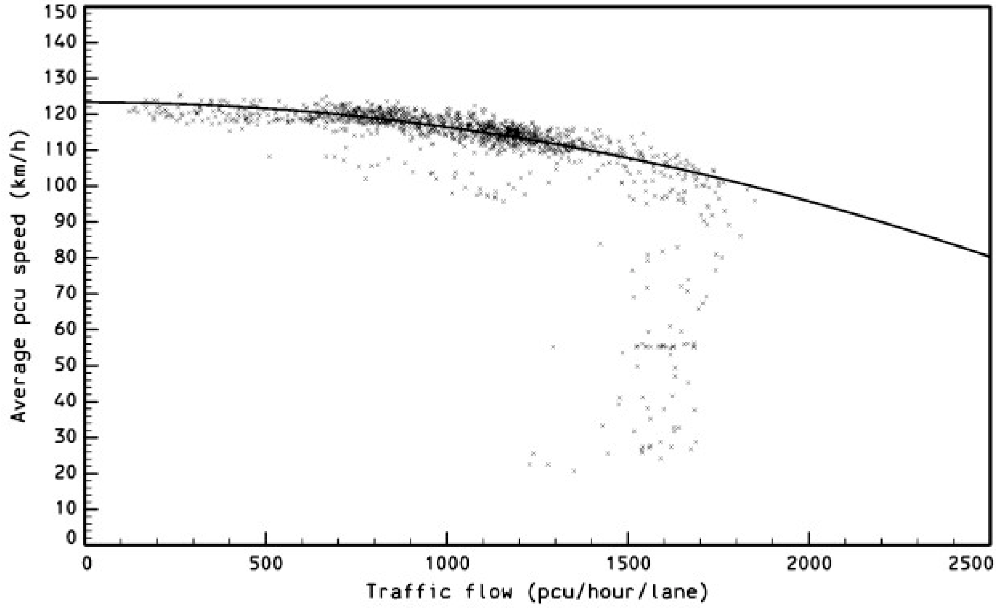

Figure 4. Example speed-flow relationship on a freeway with unstable operating conditions (observations in 15-minute intervals).

Figure 5 shows a "headway - following speed relationship" at various observation stations. The relationships were obtained for light vehicles that follow each other (at approximately the same speed). The headways shown in the figure are the ones that have the highest frequency of occurrence (the mode of the distribution). It provides an indication of average following headway, but it is not the average following headway. The figure shows that drivers maintain the same headway of about 1 second for speeds above 80 km/h, even for speeds of 140 km/h and higher.

Theoretically, if all drivers were travelling in queues, a capacity of approximately 3600 pcu/hour/lane would be possible. At such flows, however, operations would become unstable, and vehicles would not be able to maintain the short headways.

The headways increase for speeds lower than 80 km/h. At a speed of 25 km/h, the headway has increased to about 2 seconds. At the lower speeds, it appears if drivers tend to follow at an headway consisting of a fixed following distance plus a fixed time component. It is, however, not clear whether this change could be the result of unstable conditions at the low speeds, but there is some indication that this could be a general phenomenon. Observations at traffic signals have indicated that the 2 second headway generally achieved during saturation flow conditions at traffic signals also occur at a speed of approximately 25 km/h. This, however, may only be coincidental and further research would be required to establish whether the above tendency would be generally applicable.

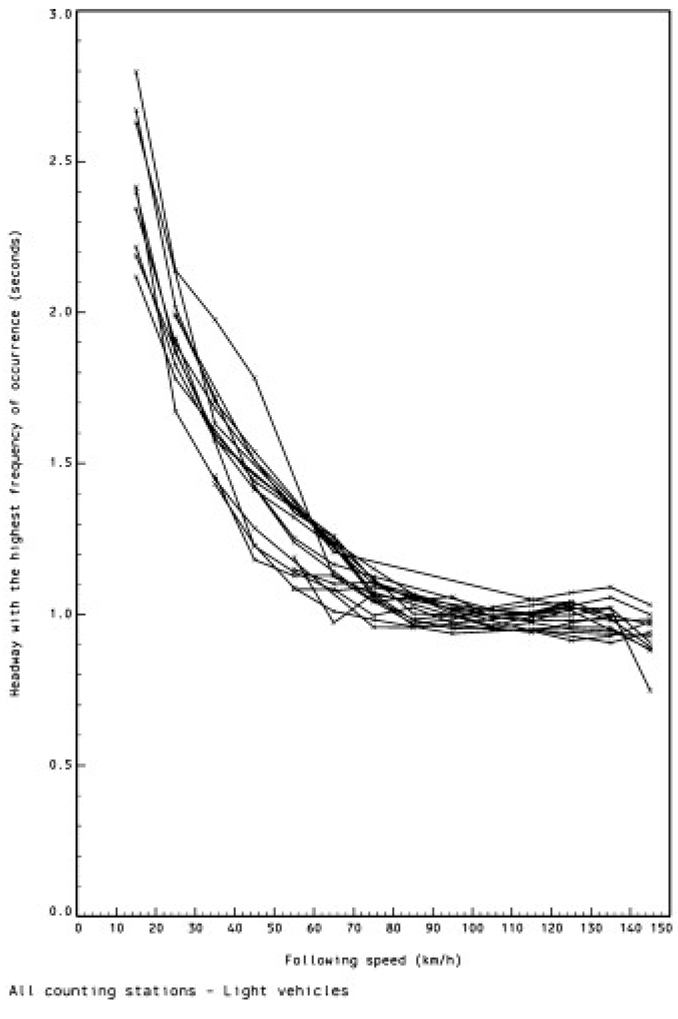

Figure 5. Following headway-speed relationship for light vehicles on various freeways.

6. CONCLUSIONS

The following conclusions can be made from the study:

- Keep left restrictions will not be effective unless drivers comply to such restrictions. A significant change in driver attitude will be required if such compliance is to be achieved.
- Relatively high flows can be achieved on freeways, but only if operating conditions are stable. Under such conditions, maximum flows of 2200 to 2350 pcu's per hour per lane have been observed. The capacity of a freeway, however, is significantly affected by elements such as congested interchanges and steep gradients.

- Vehicles follow at relatively short headways, but only when conditions are stable and speeds are relatively high (above 80 km/h). The longer headways at lower speeds could mean that capacity could be affected by reducing speeds.
- The PCU factors of heavy vehicles were found to be relatively low, varying typically between about 1,2 and 2,0. These values correspond to those given in the Highway Capacity Manual (2000), but are contrary to the general perception that heavy vehicles in South Africa have a greater impact on the flow of traffic compared to vehicles in the United States. This perception is not supported by the findings of this study. More research, however, is required to determine whether this finding can be generally applied to freeways in South Africa.

Disclaimer: It is important to note that the above conclusions are only applicable to the freeways investigated during the study. More research is required to establish whether the findings would be applicable to freeways in general.

7. REFERENCE

Transportation Research Board, 2000, *Highway Capacity Manual*, Washington D.C.

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Biography

Terry Markman is a consultant to Arup where he was a Director until 1993. He has had 30 years experience in the field of traffic and transportation engineering, transport policy, public transport, urban infrastructure, labour intensive projects and airport engineering.

He founded the Transportation Foundation of South Africa to promote the development of black entrepreneurs in the transport industry. He was involved with the Young Entrepreneur Foundation to promote entrepreneurship among the youth; the National Transport Forum and the transport committee of NAFCOC

He was a member of the Strategic Management Team for Gautrans and a member of the committee reviewing passenger transport policy for South Africa. He was responsible for the preparation of a public transport policy for DBSA. He is the author of a book "Transport Policy – A Study of Road Passenger Transport" – as a response to the Commission of Inquiry into Bus Passenger Transportation.

He was a member of the steering committee which reviewed the Domestic and International Aviation Policy for South Africa and has been responsible for numerous transport policy projects.

He was the project engineer for Arup who were appointed to assist Gauteng with the Congestion Strategy.