THE PERFORMANCE OF THE HIGH OCCUPANCY VEHICLE LANE ON THE N2 NEAR CAPE TOWN

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1. Introduction

Transportation is a crucial element to every part of our society. However, the infrastructure needed to sustain our current system becomes increasingly expensive. Therefore, in order to conserve scarce financial resources, optimum utilisation must be achieved from existing facilities. One way of achieving this is by increasing the capacity of existing facilities such as freeways. This can be done by either increasing the number of passengers per vehicle, or to provide preferential treatment to high occupancy vehicles (HOV's) on freeways. The types of HOV's applicable to South African conditions are taxis and buses. In a paper published by the National Department of Transport (*Moving South Africa (2))*, it was stated that if dedicated infrastructure like HOV lanes (bus/taxi-lanes) can improve speed on dense corridors by 25 %, it could save between 5% and 20% of operating costs.

Furthermore, between 1972 and 1996, the number of cars in South Africa increased by 72% *(2)*. This phenomenon is a direct result of low car operating costs, ineffective land use patterns, inferior public transport alternatives, and a large infrastructure investment in roads. The fact that car costs are relatively low and likely to decline towards 2020, combined with incomes that are expected to rise, will ensure that more people will be able to afford cars in the future. Future forecasts suggest that car ownership will increase by a further 64% by 2020, which in turn will increase congestion and pollution considerably.

2. Objective of the Study

The objective of this study is to investigate the performance of the bus/taxi-lane on the N2 freeway westbound towards Cape Town during peak morning conditions (06:30 – 09:00). This is achieved through the application of a number of speed-flow curves established for a section on the particular N2 freeway, as well as other speed-flow curves established for similar sections on the N1 freeway close to Cape Town (*Roux* (1)). The aim is therefore to make predictions regarding the influence of the bus/taxi-lane on the traffic situation on the particular section.

To this end, the current performance of the section was investigated and compared by way of the performance of a number of hypothetical cases. Passenger travel-times and time costs, as well as vehicle operating costs, were used as performance criteria. The different hypothetical cases are:

- Hypothetical Case 1
  An investigation into the traffic situation on the N2 freeway without the influence of the bus/taxi-lane lane.
- Hypothetical Case 2
  An investigation into the traffic situation on the N2 freeway with perfect operation of the bus/taxi-lane lane.

21st Annual South African Transport Conference
'Towards Building Capacity and Accelerating Delivery'
ISBN: 0-620-28855-8
South Africa, 15 - 19 July 2002
Conference organised by: Conference Planners
CD-ROM produced by: Document Transformation Technologies

For the first investigation, the N2 freeway was evaluated in terms of the current operating conditions with regard to travel-times and costs for each lane. This was achieved by applying the speed/flow/density relationships for this section (*Roux* (1)) to average 5 min. data (average data obtained from 5 consecutive 1 min. intervals) in order to convert average vehicular flows to equivalent average speeds for each mode on each lane. Once the speeds were determined, the passenger travel-times, as well as the passenger time costs and vehicle operating costs (as a function of average vehicle speeds), could be determined.

Similar methods were used for investigating each of the two hypothetical cases, the fundamental difference being that speed/flow/density curves established for other freeway sections (*Roux* (1)) were used to analyse 5 min. vehicle flows on each lane of the N2. Various assumptions had to be made for each of the hypothetical cases investigated in this report.

3. Vehicle Occupancy

Information was needed regarding the number of passengers occupying each type of mode observed on the N2. In this report, distinction was made between passenger cars, minibus taxis, trucks, and buses.

For the passenger car mode, a large number of occupancy observations were made during typical peak morning conditions. Table 1 contains occupancy data measured on the N2.

Table 1: Passenger-car Occupancy observations

Occupancy Class	Number of Cars	Total No. of Passengers
1	317	317
2	251	502
3	87	261
4	39	156
5	11	55
	705	**1291**

The first column in Table 1 contains the different occupancy levels (persons per vehicle), while the second column consists of the total number of observations made for each occupancy level. The third column consists of the total number of weighted observations (product of column 1 and column 2). Passenger car occupancy was then calculated as 1.831 (passengers/pc) by dividing the total number of weighted observations (column 3) by the total number of observations (column 2). This value was used for analysis throughout the report. A value of 2 passengers/veh (including the driver) was assumed for trucks.

In the case of minibus taxis and buses, it was not possible to obtain accurate occupancy levels through simple observation. For minibus taxis, the assumption (based on enquiries from the taxi industry itself) was made that taxis generally operate at passenger capacity. Bearing in mind that the average capacity of a minibus taxi is about 15 passengers (seated), a value of 16 occupants/taxi (including the driver) was assumed for minibus taxi occupancy throughout the report.

The capacity of the average single-storey bus is about 84 passengers (67 seating, 17 standing). However, it is not easy to determine the occupancy at which buses operate, due to the fact that buses (unlike taxis) operate on fixed time schedules. A capacity value of 85 passengers/veh (including the driver) was assumed for buses in this report. For the purpose of analysis, after numerous observations, it was assumed that buses operate at 90% of capacity during the morning peak period.

4. Travel-time Analysis

4.1 Current Situation

4.1.1 Description

The current situation on the N2 freeway westbound towards Cape Town was investigated during the peak $1^1/_2$ hour (06:32 to 08:01) on a typical weekday. A peak $1^1/_2$ hour was used for analysis, as this was the period during which a very high demand was experienced. For the current situation (and each hypothetical case), flows observed during the study period were used as input data for determining the total passenger travel-time (including the driver) (sec/km) for each mode type.

4.1.2 Method

The 1 min. flows observed for each lane during the given study period were converted to average 5 min. flows in pcu/h (pcu = equivalent passenger car unit). From the average 5 min. flows, average 5 min. densities (pcu/km) for each lane were calculated from the flow-density model determined for this section of the N2 (*Roux* (1)). Once the average flows and densities were known for each lane, the average pcu speeds (km/h) could easily be determined from the steady state equation $Q = U.K$ where U is the space mean speed and K is the density. The speeds were then converted to average travel-times per kilometre (sec/km/veh) for each 5 min. interval of each lane. In other words, each vehicle (irrespective of the mode) travelling on a specific lane during a specific 5 min. interval, will have the same average speed (and travel-time) as every other vehicle travelling on the same lane during the same 5 min. interval. The average travel-times, calculated for each 5 min. interval of each lane, were then assigned to each of the observed vehicle modes. Total passenger travel-times in sec/km for each mode were calculated by multiplying the total vehicle travel-time for each 5 min. interval by the relevant occupancy value. The average travel-time per passenger for each mode-type during each 5 min. interval (all lanes) was calculated next. This was done by dividing the total passenger travel-time for each 5 min. interval (each mode) by the total number of passengers observed during the particular 5 min. interval.

4.1.3 Results

For the current situation, the total travel-time of all passengers travelling through this section of the N2 during the given $1^1/_2$-hour period is determined as 4,943,851 sec/km (sum of all travel-times for each lane). From this value, the average passenger travel-time for the whole period (irrespective of the mode) can be calculated as 161 sec/km/passenger. Likewise, the average speed can be calculated as 22.33 km/h/passenger. Also, the percentage violation (number of passenger cars and trucks as a percentage of the total number of vehicles) on the bus/taxi-lane is calculated as 70.1%. Of this percentage, 69.6% are passenger cars and the rest trucks.

Table 2 contains data on the total number of vehicles (and passengers) counted for each type of mode during the whole $1^1/_2$-hour peak period.

Table 2: Composition of mode types and passengers for peak $1^{1}/2$-hour

Mode Type	Vehicles		Passengers	
	Total	%	Total	%
Passenger cars	4783	82.2	8758	28.6
Taxis	767	13.2	12272	40.0
Trucks	149	2.6	298	1.0
Buses	122	2.1	9333	30.4

4.2 Hypothetical Case 1: N2 freeway without bus/taxi-lane

4.2.1 Description

The first hypothetical case is an investigation into the traffic situation on the N2 freeway without the influence of the bus/taxi-lane. To this end, the current traffic-flow data observed on N2 during the $1^{1}/_{2}$-hour peak period were analysed and converted to equivalent passenger travel-times by applying the speed-flow curves of a section on the N1 freeway near Century City (*Roux* (1)). The assumption was therefore made that the particular section on the N2 freeway would operate similarly to the three-lane section on the N1 freeway in absence of a lane dedicated to taxis and buses. Therefore, it was assumed that taxi drivers exhibit driver behaviour similar to that of passenger-car drivers on freeways.

4.2.2 Method

The method used to determine passenger travel-times was very similar to the method used for the current situation, the fundamental difference being that the 5 min. flows observed for the N2 had to be redistributed among the three lanes. This had to be done in such a manner that would suggest that the bus/taxi-lane did not exist. Firstly, the flows were distributed among the three lanes according to the pcu ratios observed for the section on the N1 near Century City, for each mode. Average speeds were then determined directly from the speed-flow curves determined for the section on the N1 freeway. The speeds were converted to average travel-times per kilometre (sec/km/veh) for each 5 min. interval of each lane. Total passenger travel-times in sec/km for each mode were calculated by multiplying the total vehicle travel-time for each 5 min. interval by the relevant occupancy value.

4.2.3 Results

For Hypothetical Case 1, the total travel-time of all passengers was calculated as 4,719,564 sec/km (slightly lower than the 4,943,851 sec/km determined for the current situation on the N2). From this value, the average passenger travel-time for the whole period, irrespective of the mode, can be calculated as 154 sec/km/passenger (vs. 161 sec/km/passenger for current situation). Likewise, the average speed can be calculated as 23.39 km/h/passenger.

4.3 Hypothetical Case 2: N2 freeway with perfect bus/taxi-lane operation

4.3.1 Description

The second hypothetical case is an investigation into the traffic situation on the N2 freeway with perfect operation of the bus/taxi-lane. For perfect operation, only taxis and buses are allowed to travel on the bus/taxi-lane during the allocated period (06:30 to 09:00). Therefore, for Hypothetical Case 2, all taxis and buses were placed on the right hand lane according to the total 5 min. flows observed for the current situation on the N2. These flows were then analysed and converted to equivalent passenger travel-times by applying the speed-flow curves determined for the bus/taxi-lane. (*Roux* (1)).

Similarly, passenger cars and trucks were placed on the left hand lane and middle lane. Due to the large number of passenger cars, the redistribution of traffic on these two lanes would almost certainly result in flows much higher than the capacity on each lane for every 5 min. interval. It is important to note that when the demand increases from free-flow conditions up to a point where the uncongested capacity of a particular lane is exceeded, flow-rates will not remain at capacity. A phenomenon known as a “breakdown in flow” occurs, which results in a sudden decrease in flow and a sudden increase in congestion. Vehicles then travel at much lower flows (congested capacity) as long as the demand exceeds the uncongested capacity. This phenomenon can be explained as a sudden shift from the uncongested side of the composite flow-density curve to the congested side. Flows on the left hand lane and the middle lane much lower than the 5 min. flows observed for the current situation are therefore expected, with vehicles being carried over to following intervals due to high congestion.

Redistributed traffic-flow data on the left hand lane and middle lane were analysed and converted to equivalent passenger travel-times by applying the speed-flow curves determined for these two lanes. However, before the curves could be applied, the flow and level of congestion for each 5 min. interval (each lane) had to be determined. Various assumptions had to be made before these flows and congestion levels could be determined. The assumptions for Hypothetical Case 2 were:

- All redistributed trucks will travel on the left hand lane only.
- Hypothetical Case 2.A: Passenger cars are expected to travel on the left hand lane and middle lane according to the worst 5 min. flows observed during congested conditions for the current situation. This is regarded as the worst possible performance that could be expected from the middle and left hand lanes during perfect operation of the bus/taxi-lane.
- Hypothetical Case 2.B: Passenger cars are expected to travel on the middle and left hand lanes according to a prescribed level of the uncongested lane capacities. The assumption is therefore that vehicle throughput on the N2 can be maintained at a high flow level on these two lanes (below capacity), with relatively high vehicle speeds. One way of achieving this is through the use of ramp metering, whereby the number of vehicles entering a freeway mainline at each on-ramp is controlled during the morning peak period. For Hypothetical Case 2.B, a conservative prescribed flow-rate of 50% of the uncongested capacity was used for each lane.
- Hypothetical Case 2.C: The assumptions of Hypothetical Case 2.B apply. A prescribed flow-rate of 85% of the uncongested capacity was used for each lane.

4.3.2 Method

The method used to determine passenger travel-times was very similar to the method used for Hypothetical Case 1. The 5 min. flows observed for Section 3 had to be redistributed among the three lanes. This was done according to the assumptions made for each particular Hypothetical case. Average speeds were then determined directly from the appropriate speed-flow curves for each lane. The speeds were converted to average travel-times per kilometre (sec/km/veh) for each 5 min. interval of each lane. Total passenger travel-times in sec/km for each mode were calculated by multiplying the total vehicle travel-time for each 5 min. interval by the relevant occupancy value.

4.3.3 Results

(i) Hypothetical Case 2A

The total travel-time of all passengers was calculated from as 7,519,762 sec/km. This very high value is due to a large number of passenger cars experiencing a very high level of congestion. The average passenger travel-time and average speed was calculated as 239.8 sec/km/passenger and 15.01 km/h/passenger respectively.

(ii) Hypothetical Case 2B

The total travel-time of all passengers was calculated as 1,129,674 sec/km. This low value is due to the assumption that a relatively high level of traffic-flow (with high vehicle speeds) can be maintained on the middle and left hand lanes through the use of ramp metering. The average passenger travel-time and average speed was calculated as 36.77 sec/km/passenger and 97.9 km/h/passenger respectively.

(iii) Hypothetical Case 2C

The total travel-time of all passengers was calculated at 1,139,487 sec/km. The average passenger travel-time and average speed was calculated as 39.14 sec/km/passenger and 91.98 km/h/passenger respectively.

The percentage violation on the bus/taxi-lane for Hypothetical Case 2 is zero, as perfect operation of the bus/taxi-lane is assumed.

4.4 Summary and Interpretation of Travel-Time Results

The travel-time results obtained for the current situation, as well as for each of the hypothetical cases, are summarised in Table 3.

Table 3: Summary of Travel-Time Results

Summary of Results	Current Situation: N2 with bus/taxi-lane	Case 1: N2 without bus/taxi-lane	Case 2: Perfect bus/taxi-lane operation		
			Worst 5 min. flows	50% of Capacity	85% of Capacity
Total passenger Travel Time (sec/km)	**4,943,851**	**4,719,564**	**7,519,762**	**1,129,674**	**1,193,487**
Passenger Cars	1,282,243	1,171,467	6,487,915	338,811	400,159
Taxi's	2,308,417	2,218,870	441,792	441,792	441,792
Trucks	73,853	60,770	254,067	13,083	15,548
Buses	1,279,338	1,268,457	335,988	335,988	335,988
Average Passenger Travel Time (sec/km)					
Passenger Cars	146.4	133.7	730.2	39.1	46.2
Taxi's	188.1	180.8	36.0	36.0	36.0
Trucks	247.8	203.9	852.6	43.9	52.2
Buses	137.1	135.9	36.0	36.0	36.0
Average Passenger Speed (km/h)					
Passenger Cars	24.59	26.92	4.93	92.17	78.00
Taxi's	19.14	19.91	100.00	100.00	100.00
Trucks	14.53	17.65	4.22	82.00	69.00
Buses	26.26	26.49	100.00	100.00	100.00
Total Avg. Passenger Travel Time (sec/km/pass.)	**161.2**	**153.9**	**239.8**	**36.8**	**39.1**
Total Avg. Passenger Speed (km/h/pass.)	**22.33**	**23.39**	**15.01**	**97.90**	**91.98**

The results of the current situation and Hypothetical Case 1 are very similar, with extremely high average travel-times obtained for each mode type. This suggests that the particular section on the N2 freeway currently operates very much like a three lane freeway section without a bus/taxi-lane. In fact, slightly lower average travel-times are predicted by Hypothetical Case 1, which suggests that the current use of the bus/taxi-lane has a negative impact on the performance of the section.

An interesting observation is that the highest average travel-times are obtained for taxis and trucks for both the current situation and Hypothetical Case 1. This is a direct result of the percentages of vehicles travelling during either congested or uncongested conditions for each mode. A higher percentage of the total number of taxis (38%) and trucks (42%) travel during congested conditions, as opposed to passenger cars (26%) and buses (25%). This gives rise to the higher average travel-times calculated for taxis and trucks.

For both the current situation and Hypothetical Case 1, passengers travelling in passenger cars account for a relatively low percentage (about 26%) of the total passenger travel-time, while passenger cars account for as much as 82% of the total number of vehicles. In contrast, passengers carried by taxis and buses (constituting 15% of the total number of vehicles) account for about 73% of the total passenger travel-time.

For Hypothetical Case 2.A, passengers travelling in passenger cars account for over 86% of the total passenger travel-time. This is a result of the extremely high level of congestion predicted for the middle and left hand lanes. In contrast, taxis and buses travel in the bus/taxi-lane at their desired speeds (100 km/h maximum) during uncongested conditions. A very high speed-differential exists between vehicles in the middle lane (average speed about 5 km/h) and taxis and buses in the bus/taxi-lane (100 km/h). Also, taxis and buses are required to weave into and out of the bus/taxi-lane in order to enter or leave the freeway. For example, a vehicle travelling on the bus/taxi-lane at 100 km/h will have to slow down to a speed of about 5 km/h in order to join the middle lane. It is therefore highly unlikely that the high speeds predicted for the bus/taxi-lane by Hypothetical Case 2 will actually occur in practice. One positive aspect of Hypothetical Case 2A is that the extremely high level of congestion in the middle and left hand lanes might force passengers to consider using public transport (as opposed to passenger cars) as their mode of choice.

Extremely low average travel-times are predicted by both Hypothetical Case 2.B and 2.C for each mode type. The different modes travel at similar speeds, resulting in a low speed differential between the middle and right hand lane, thereby facilitating weaving into and out of the bus/taxi-lane.

Hypothetical Case 2.B predicts lower average passenger travel-times for passenger cars and trucks than Hypothetical Case 2.C, notwithstanding the fact that higher flow-rates are prescribed by Hypothetical Case 2.C. It must however be borne in mind that the total number of passenger cars and trucks were able to travel through the section during the $1^1/_2$-hour period for Hypothetical Case 2.C. In contrast, only about 60% of the passenger cars and 84% of the trucks were able to do so for Hypothetical Case 2.B. The extra time spent by vehicles outside the $1^1/_2$-hour period before entering the section, was not taken into account while determining the average passenger travel-times.

Due to the lower prescribed flow-rates, longer queues and delays are expected on the on-ramps for Hypothetical Case 2.B. Hypothetical Case 2.C is therefore preferred above Hypothetical Case 2.B.

5. Total Cost Analysis

The total costs of using the N2 freeway section, under the different circumstances described in the previous section, consist of vehicle operating costs and person time costs. The operating cost of a particular vehicle is a function of the average travel speed of the vehicle over a certain length of road. On the other hand, a person time cost is a measure of the value of a particular person's time. The additional time that is spent by a person while travelling is regarded as "lost" time, expressed as R/person-hour. The value of a particular person's time is dependent on the nature of his/her journey. For example, persons travelling to or from work (commuters) have lower time values than persons who are working while travelling (e.g. bus and taxi drivers).

5.1 Vehicle Operating Costs

Table 4 contains operating costs per type of mode for various average travel speeds (expressed in 1999 R/1000 vehicle kilometres). The operating cost data were obtained from the CSIR (Council for Scientific and Industrial Research) (3). Elements incorporated into the costs include fuel, vehicle maintenance, depreciation, tyres, and oil.

Table 4: Vehicle Operating Costs

1999 Vehicle Operating Costs (R/1000 veh. km.)				
Travel Speed	**Passenger Cars**	**Taxi's**	**Buses**	**Trucks**
10	1129.51	1306.11	2742.55	3736.91
20	830.41	947.98	1993.61	2619.32
30	713.24	821.22	1734.96	2235.55
40	649.03	759.92	1614.98	2048.17
50	609.87	729.37	1561.72	1951.06
60	586.00	717.96	1551.93	1912.22
70	573.20	720.93	1576.82	1921.41
80	569.41	736.22	1633.38	1976.87
90	573.57	763.04	1721.37	2080.85
100	585.21	801.27	1842.20	2237.85
110	604.14	851.20	1998.42	2453.86
120	630.38	913.44	2193.50	2736.02

Vehicle operating costs were determined for the current situation, as well as for each of the hypothetical cases described in the previous section. Table 4 was used to calculate operating costs for each mode type from corresponding 5 min. average speed data.

5.2 Person Time Costs

The value of a particular person's time is dependent on the nature of his/her journey. In this report, distinction was made between commuter passengers and working passengers (truck passengers and drivers, taxi drivers, and bus drivers). A time-cost value of R5.45 per person-hour was assumed for commuter passengers, and R23.89 per person-hour for working passengers. These values were obtained from the CSIR (3).

Person time costs were calculated from average travel-time data for each 5 min. interval. These values were converted to equivalent person costs per travel distance (R/km) for each mode type.

5.3 Summary and Interpretation of Total Cost Results

The total cost results (operating costs and person time costs) obtained for the current situation, as well as each of the hypothetical cases, are summarised in Table 5. The person time costs are expressed in R/km.

Table 5: Summary of Total Cost Results

Summary of Total Cost Results	Current Situation: N2 with bus/taxi-lane	Case 1: N2 without bus/taxi-lane	Case 2: Perfect bus/taxi-lane operation		
			Worst 5 min. flows	50% of Capacity	85% of Capacity
Total Vehicle Operating Costs (R/km)	**5,293.99**	**5,158.95**	**11,180.53**	**3,987.74**	**3,975.58**
Passenger Cars	3,710.82	3,618.97	9,119.52	2,819.94	2,822.93
Taxi's	810.38	804.95	622.01	622.01	622.01
Trucks	513.05	472.15	1,209.83	316.63	301.48
Buses	259.73	262.88	229.16	229.16	229.16
Total Person Time Costs (R/km)	**8,902.60**	**9,045.88**	**12,905.92**	**1,997.66**	**2,106.89**
Passenger Cars	1,941.17	1,773.47	9,821.98	512.92	605.80
Taxi's	4,233.70	4,069.47	810.26	810.26	810.26
Trucks	490.10	403.27	1,686.02	86.82	103.18
Buses	2,237.63	2,799.66	587.66	587.66	587.66
Total Costs (R/km)	**14,196.59**	**14,204.83**	**24,086.45**	**5,985.40**	**6,082.48**
Passenger Cars	5,651.99	5,392.44	18,941.50	3,332.86	3,428.73
Taxi's	5,044.09	4,874.42	1,432.27	1,432.27	1,432.27
Trucks	1,003.15	875.43	2,895.85	403.45	404.66
Buses	2,497.37	3,062.54	816.83	816.83	816.83
Average Total Cost/person (R/km)	**0.45**	**0.45**	**0.76**	**0.19**	**0.19**
Passenger Cars	0.65	0.62	2.16	0.38	0.39
Taxi's	0.41	0.40	0.12	0.12	0.12
Trucks	3.37	2.94	9.72	1.35	1.36
Buses	0.24	0.30	0.08	0.08	0.08

The total costs of the current situation are very similar to the costs of Hypothetical Case 1. This is again proof that the particular N2 freeway section currently operates very much like a three lane section without a bus/taxi-lane. However, the total person time costs for bus passengers were slightly lower for the current situation (as opposed to that of Hypothetical Case 1). This results from the fact that a large portion of buses (94%) travelled on the bus/taxi-lane lane during the current situation where the highest congested flow-rate occurred.

For both the current situation and Hypothetical Case 1, passenger cars account for about 70% of the total operating costs, while passengers travelling in passenger cars only account for about 20% of the total person time costs. In contrast, taxis and buses together account for only 20% of the total operating costs, while accounting for between 73% and 76% of the total person time costs.

For Hypothetical Case 2.A, the high level of congestion in the middle and left hand lanes result in extremely high operating costs and person time costs for passenger cars and trucks. On the other hand, total costs (especially person time costs) for taxis and buses are reduced considerably. As mentioned earlier, the extremely high levels of congestion in the middle and left hand lanes, resulting in high costs, might promote a shift to public transport as the optimal mode of transport.

A large reduction in operating costs and person time costs are predicted for all mode types by both Hypothetical Case 2.B and 2.C. However, Hypothetical Case 2.C is preferred above Hypothetical Case 2.B, as the extra costs incurred by vehicles outside the $1^1/_2$-hour period before entering the section (Hypothetical Case 2.B), were not taken into account while determining the total costs. It is however not possible to predict the full impact of the hypothetical case on traffic behaviour. In practice, drivers might alter their travel routines by either changing their trip schedule, or choosing alternative travel routes at greater cost.

Refer to the Average Total cost per person km for each of the hypothetical cases. It is evident that both Hypothetical Case 2.A and 2.B predict a significant reduction in total cost per km for each mode. The result is an average saving of about R 0.26 per person km during the morning peak period.

6. Conclusions

(i) The results of Hypothetical Case 1 suggest that the particular section currently operates very much like a three-lane freeway section without a bus/taxi-lane. This points to a total disregard by unauthorised vehicles (e.g. private cars) to the fact that the lane is dedicated to HOV use during morning peak conditions.

(ii) When perfect operation of the bus/taxi-lane was assumed (Hypothetical Case 2), significant improvements in travel-times and travel costs were experienced for both taxis and buses. It is believed that effective law enforcement is one way of improving operation of the bus/taxi-lane. Another way may be to utilize the bus/taxi-lane as an express lane (with no enter/exit capability) in order to avoid traffic on the lane being stopped by vehicles trying to exit into the jammed middle lane.

(iii) Very high passenger car travel-times and costs were predicted by Hypothetical Case 2.A. This is due to extremely high congestion on the middle and left hand lanes of the N2 freeway section. It is expected that the poor performance of these two lanes will force passengers to consider public transport (as opposed to passenger cars) as the optimal mode of transport.

(iv) Hypothetical Case 2.A predicts a very high speed-differential between traffic in the middle lane and the bus/taxi-lane (median lane). As taxis and buses are required to weave into and out of the bus/taxi-lane in order to enter or leave the freeway, it is believed that the high speeds predicted for the median lane (fast lane) will in fact be much lower in practice.

(v) A large reduction in both overall travel-times and overall travel costs can be obtained when the flow-rates on the middle and left hand lanes are regulated (Hypothetical Case 2.B and 2.C). This can be achieved by restricting access to the freeway at the on-ramps with the use of ramp metering.

(vi) Lower flow-rates are prescribed for the middle and left hand lanes for Hypothetical Case 2.B (50% of capacity as opposed to 85% of capacity for Hypothetical Case 2.C). Hypothetical Case 2.C therefore provides the ultimate solution, as longer queues and delays are expected on the on-ramps for Hypothetical Case 2.B.

7. Recommendations

- Future studies might focus on finding a way to force passenger cars to stay clear of the HOV lane during conditions of high congestion.
- Further research is required to evaluate the impact of speed differential between adjacent lanes on traffic flow characteristics (e.g. lane capacity, safety, following distance, breaking distance, etc.)
- A large reduction in both overall travel-times and overall travel costs were observed when access to the freeway was restricted at the on-ramps. However, the values did not include delays and costs incurred by vehicles queuing at the on-ramps. Further research is necessary to determine queue lengths and delays experienced by vehicles at on-ramps for different flow-rates.
- The choice of mode by a particular passenger is based on the utility (attractiveness) of each mode to that particular passenger. The utility of a particular mode is based on factors like travel-time (travel-speed), safety, convenience, cost and accessibility. Further research is necessary to determine average utility values for different passenger types (based on socio-economic and demographic factors). This will enable further quantification of benefits for each of the hypothetical cases.

8. References

1. Roux, J. *Establishing and Applying Speed-Flow Relationships for Traffic on South African Freeways*. University of Stellenbosch, 2001.
2. South African National Department of Transport, *Moving South Africa: A Transport Strategy for 2020,* 1999.
3. NITRR Computer Information Centre for Transportation. *Computer program COSTDATA – May 1999 version.* Pretoria, 1999.

THE PERFORMANCE OF THE HIGH OCCUPANCY VEHICLE LANE ON THE N2 NEAR CAPE TOWN

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