

TRAFFIC SIGNAL CO-ORDINATION ALONG CONGESTED ARTERIALS

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1. BACKGROUND

The mighty Zambezi Drive, not very much unlike the great Zambezi River, is a major arterial in the north of Pretoria. It is a major road running in an east - west orientation that carries a very high volume of traffic, together with a substantial proportion of heavy vehicles. The travel speeds are also relatively high, typically faster than the posted speed limit of 80 km/h. The traffic enters Zambezi Drive from a number of side roads (tributaries)

A comprehensive project was undertaken to improve traffic operations along Zambezi Drive. This paper addresses one very important component of this project, the proper co-ordination of traffic signal along the route.

2. INTRODUCTION

The aim of co-ordinating traffic signals is to improve traffic flow through the system. A traffic system is formed when two or more traffic signals no longer operate independently. The system can either be linear (arterial) or in a network (such as a CBD grid). It is expected that co-ordination of traffic signals in a network is more complicated. The need for a large number of calculations, especially with regard to iterations needed, requires the use of analysis software.

The co-ordination of traffic signals depends on a number of factors. The basic formulation is a relation involving speed, distance and time (signal cycle time) and is given by the formula below which is derived from Figure 1:

$$V = \frac{2L}{C}$$

Where

V = progression speed in m/s
L = intersection spacing in m
C = cycle time in seconds

The selection of intersections to form part of the co-ordinated system is one of the most important features. The interaction between traffic at the various intersections must be taken into account. In order for signals to be co-ordinated, it is essential that a common cycle length be chosen. Typically the optimum cycle length of the critical intersection on the network will be chosen, although a longer cycle length may be chosen if it would improve co-ordination. The other dimensions of the co-ordination effort involve intersection spacing (distance between intersections) and speed of movement.

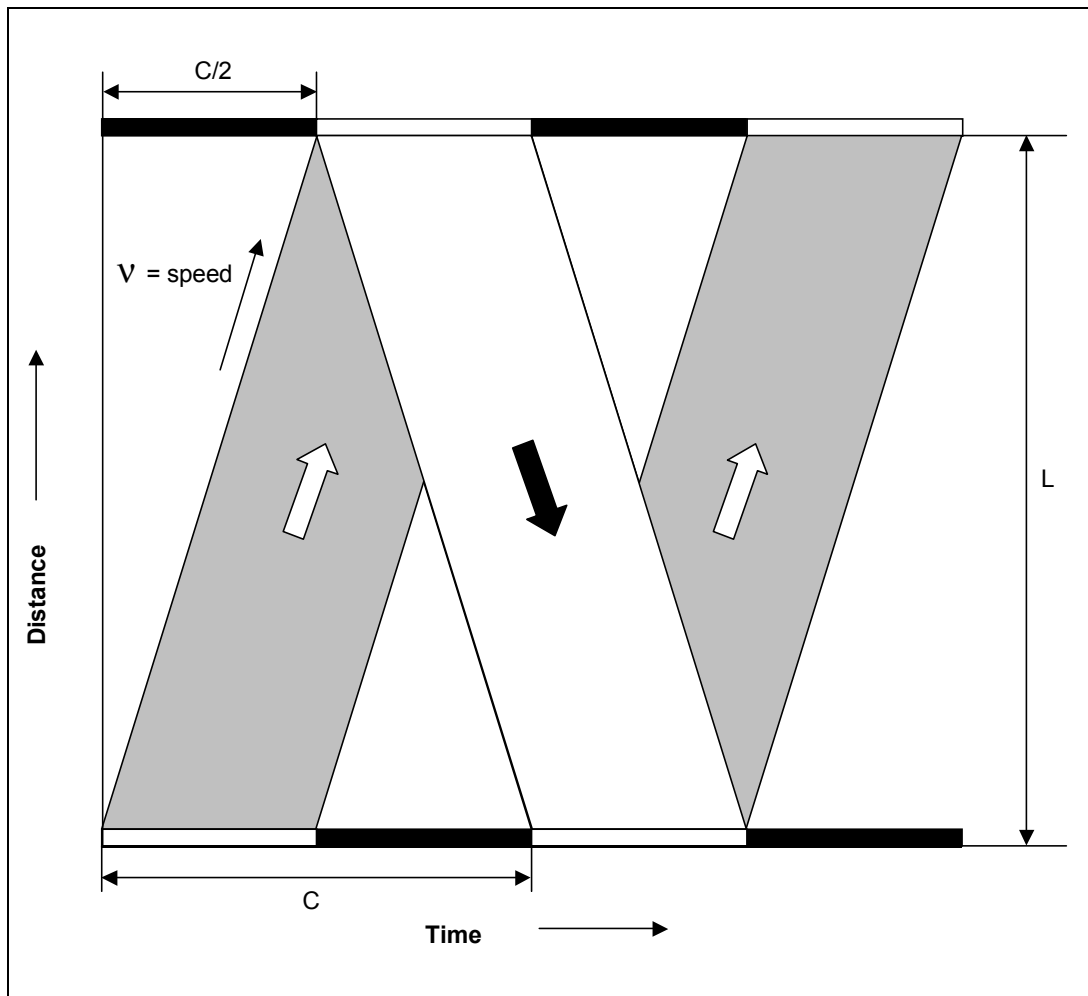


Figure 1 : Relationship between progression speed, cycle time and distance

3. CO-ORDINATION OF TRAFFIC SIGNALS ALONG ARTERIALS

The co-ordination of traffic signals along arterial routes, in order to optimise traffic flow, is a complicated process. There are a large number of variables that have to be taken into account. The movement of vehicles in platoons is one of the more important variables. The platoon dispersion, ie the separation of individual vehicles in terms of time headway, is a further consideration in the definition of optimum traffic flow. Among the more common objectives/descriptions include: *Minimise delay*, *Minimise stops*, *Minimum performance index*, consisting of a weighted average of stops and delay.

The process is further complicated in cases where over-saturated conditions are encountered. The effect of residual queues must be taken into account. The variable queue lengths makes it difficult to predict the time adjustments that have to be made to compensate for delays due to queued vehicles that have to clear the intersection.

4. TRADITIONAL SOFTWARE USED FOR CO-ORDINATION

There is a range of software that has over the years been used to do co-ordination of traffic signals, particularly on arterial routes. By and large none of these models have produced very good results directly from their outputs, and additional iterations of fine-tuning are frequently required to improve settings. Some of the more common software are mentioned below.

TRANSYT

This software solution was first developed by the TRL in England in 1967. It is a particularly powerful tool, and is capable of doing co-ordination in networks as well as along arterials. The program has been refined through several versions. Expansion has been done both in England, where the latest version 10 has been released, as well as in the United States where Transyt 7F is in use.

SYNCHRO

The SYNCHRO and TrafSim suite offers a highly graphical and easy to use option in the analysis of individual intersections and networks. It features a modified vehicular delay prediction methodology.

PASSER II

The main aim of Passer II is to optimise the green bandwidth along arterial roads. It is not applicable to networks, as it does not consider side road bandwidths.

NETSIM

This is a micro-simulation model, and has come to the fore recently, particularly with the improvement in desktop computer processing power over the past 6 to 8 years. As a micro-simulation model, the program models the behaviour of each individual vehicle as it traverses the system.

TSPD-DRAFT

This program provides a graphical solution to space time diagrams and platoon progression diagrams. It does very limited analysis, although it permits quick and easy iterations and scenario evaluations

SUMMARY

The various software solutions have a basic premise of simplifying the large number of calculations required to successfully predict the flow of traffic in a co-ordinated system in an attempt to ensure that the maximum number of vehicles were not disadvantaged by having to stop or be delayed unnecessarily.

5. ISSUES ARISING/DEFICIENCIES IN EXISTING.

There are a number of areas in which the various models have failed to consistently improve traffic flow. The outstanding deficiencies that have been identified involve the following aspects:

- Queue formation and the effect of residual queues
- The manner in which Platoon dispersion is handled
- Incorrect usage of performance index as an optimisation criterion
- Accuracy of optimisation methods: local minimums found due to use of hill-climbing method
- Consideration of vertical queues and instantaneous acceleration of vehicles

It must be borne in mind that the deficiencies relate more to the actual implementation, and not the consideration of the concept within the model.

6. METHOD APPLIED

The method applied and evaluated during the revision of the traffic signal settings along Zambezi Drive consists of a program developed by Prof van As.

OUTLINE OF MODEL AND KEY CHARACTERISTICS

The model incorporates the following features of existing programs such as TRANSYT:

- Queue formation and its impact on progression
- Platoon dispersion

Unique features of the model are

- Different platoon dispersion options depending on whether the platoon has stopped or not at the previous intersection
- Ability to give significantly more weight to stops compared to delay. This was found to improve progression significantly
- Ability to adjust signal settings using an interactive user-friendly method, thus addressing the problem of local minima

The program is not considered to be fully developed yet, and some of the short-comings that have been identified include:

- The program currently operates under MS-DOS
- The program does not take short block lengths and the blocking of an intersection by vehicle queues into account
- Effects of short turning lanes are not taken into account. The user can however reduce the saturation flow of a turning lane.

The project highlighted shortcomings in existing models. The introduction of this model is considered a step in the right direction, but further development is required.

APPLICATION

In descriptive terms, some key considerations of the application of the model described are as follows:

It takes cognisance of vehicle queues at downstream intersections in optimizing the off sets along an arterial. The queues are obtained by determining the arrival and departure patterns at the stop line. The simulated arrival pattern takes the dispersion of vehicle platoons along the arterial into account. It also takes the arriving vehicles that have turned into the arterial road from the preceding side road into account.

The offsets are determined by timing arrival of the platoon of vehicles travelling along the arterial at the intersection to coincide with the dissipation of the queue at the intersection. This is shown diagrammatically on Figure 2

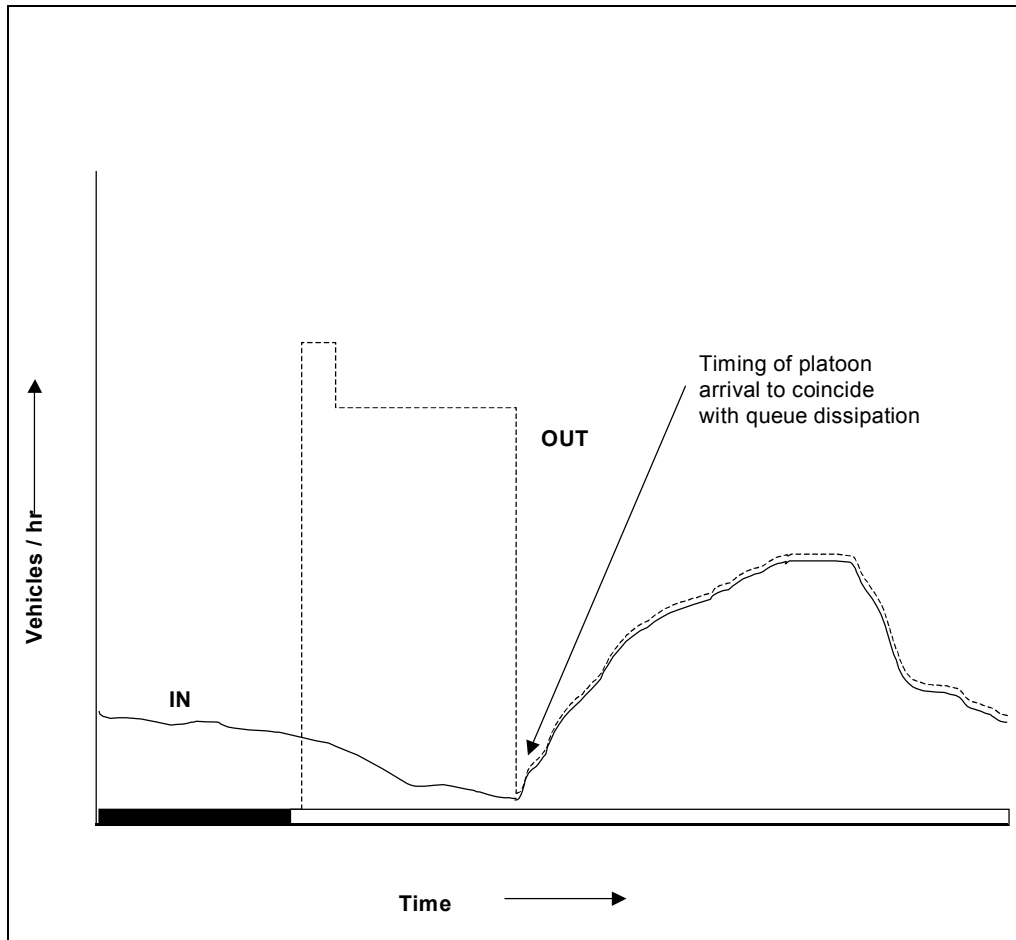


Figure 2 : Platoon arrival on departure of queue

The program provides a visual representation of the arrival and departure flow patterns at each intersection along the arterial as well as the departure of the first vehicle from the stop line and the arrival of the same vehicle at the down stream intersection.

A typical display of the platoon movement through the arterial is shown on Figure 3

The program allows for the interactive adjustment of the green splits and off sets at each intersection. The effect of the adjustments on the flow patterns and progression are shown on the screen

7. DATA INPUT REQUIRED

The program requires the following data input:

- Link length
- Lane configuration
- Saturation flows for different lane types
- Cycle length
- Traffic demand both along the arterial and on the side roads
- Progression speed. Different progression speeds can be provided over different sections in order to simulate driver behaviour.
- The programme can determine green splits at intersections. Alternatively the green splits can be provided as an input. The programme can accommodate leading and lagging right turn phases.

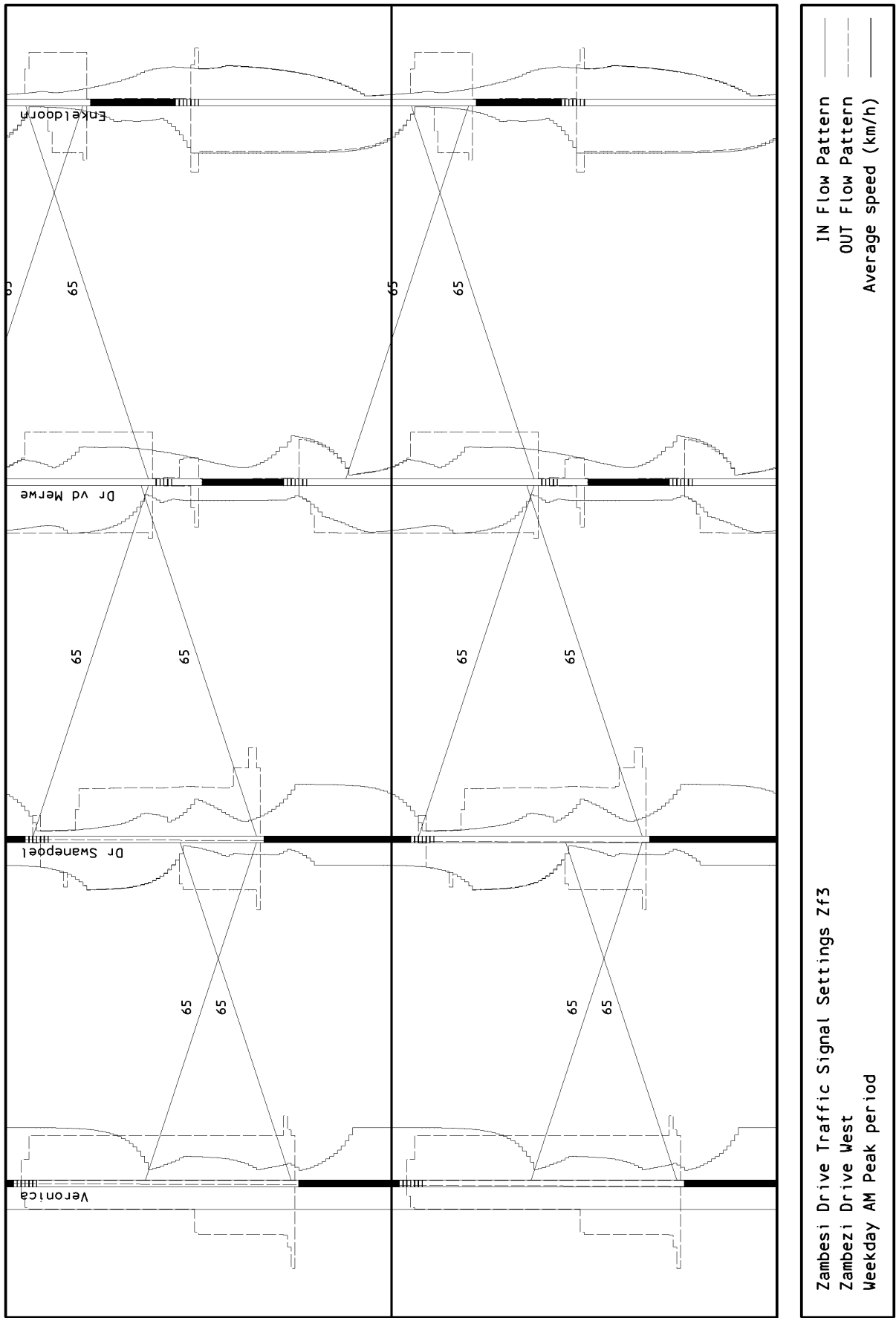


Figure 3 : Typical output indicating flow patterns at intersections

8. CASE STUDY: ZAMBESI DRIVE

BACKGROUND AND OPERATIONAL CHARACTERISTICS

Zambezi Drive consists of a highly trafficked urban arterial route. The geometric design is a dual carriageway road to provincial authority standards. The road is characterized by traffic queues in particular in the eastbound direction during the morning peak hour.

The traffic queues observed during the morning peak on the western approach to the Breed Street intersection are shown on Photograph 1. The queues almost extend to the previous intersection, which represents a distance of approximately 1.7 km

Different cycle lengths had been used during the morning peak at the N1 freeway on- and off ramps and the adjacent intersections to improve capacity. A cycle length of 120 seconds was used at the interchange and two adjacent signals, whilst the remainder operated at a cycle length of 90 seconds



Photograph 1 : Traffic queues on western approach to Breed Street intersection prior to implementation

Cycle length

The use of a common cycle length was recommended although the intersections where different cycle lengths were applied are spaced approximately, 1.7 km apart.

Observations were made of saturation flows for different times using an event logger. Care was taken to ensure that the saturation flow was not affected by down stream traffic queues. The results are shown in Table 1:

Table 1 – Observed Saturation Flow at intersection of Zambezi Drive and Breedt Street / Visvanger Street

Cycle length (s)	Observed saturation flow (v / hr)	Lost time (3 phase signal)	Effective green time (s)	Saturation flow (v / s)	Capacity / lane (v/hr)
90	1 910	560 s / hr	3 040	0.5306	1 613
100	1 900	504 s / hr	3 096	0.5278	1 634
120	1 651	420 s / hr	3 180	0.4586	1 458

The results indicate that the highest saturation flow along Zambezi Drive was achieved at a 100-second cycle length. A common cycle length was recommended along Zambezi Drive to allow co-ordination of traffic signals. The use of a 100-second cycle length was therefore recommended during the morning and the afternoon peak hours.

OUTPUT

The program provides off sets to be used along the arterial road as determined during the optimisation process and adjustments made using graphical output.

EVALUATION OF OPERATING CONDITIONS

Before

Travel time surveys were done along Zambezi Drive during the morning peak hour in the eastbound band direction prior to implementation of the revised signal settings. The travel time surveys were done just prior to the December vacation and the results are therefore not conclusive.

Photograph 1 indicates that arriving platoons are not distinguishable during the morning peak as the queues on the western approach to the Breedt Street intersection extend backwards up to Enkeldoorn Street.

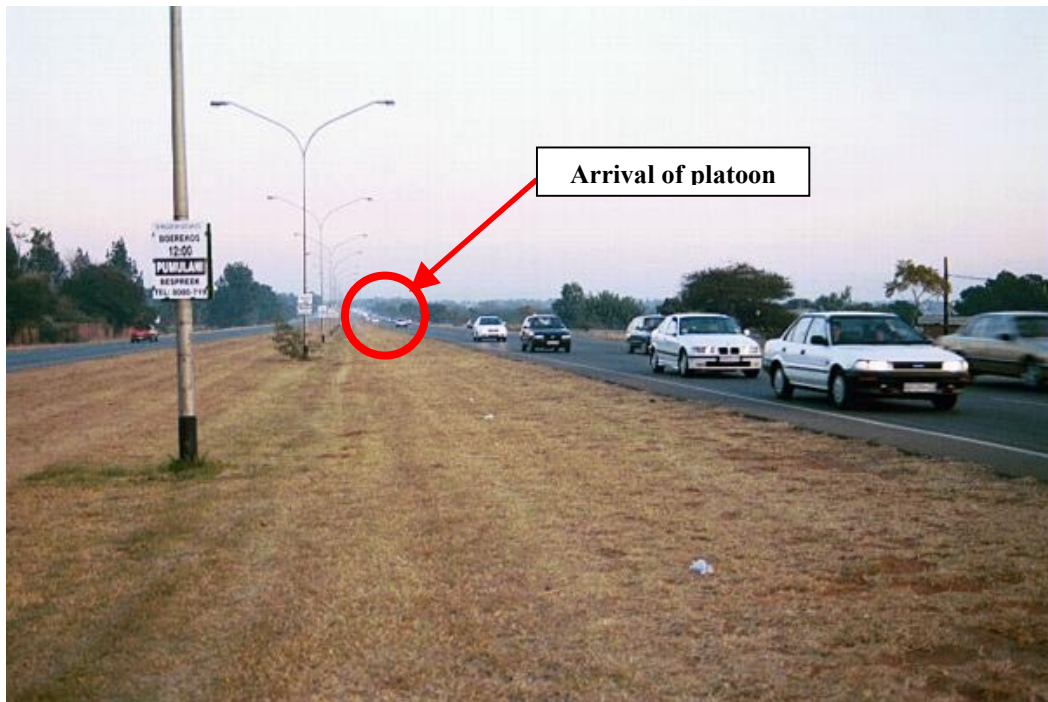
After

At the time of writing, the signal settings were still being implemented. The traffic patterns in the study area were also affected by the closing of one of the major intersections in the study area (Dr Swanepoel Drive) for construction work. This prevented conclusive results in respect of travel time surveys.

Flow pattern observations during the morning and afternoon peak hour indicated that the platoon arrives when the back of the queue starts moving. This situation is shown on Photograph 2.

During the morning peak, under over saturated conditions, with rapid queue growth observed in the peak 15 minutes, arrivals of the platoons occurred prior to dissipation of the queues at the stop line. This can probably be attributed to the insufficient capacity of the right turn movement from Zambezi Drive onto the N1 freeway in a south bound direction to accommodate the demand during the peak 15 minutes. This results in vehicles queuing through the adjacent intersections, which results in residual queues and growth in traffic queues.

Slow continuous movement of the traffic stream was observed under these conditions. Vehicles were timed from joining the back of the queue on the western approach to the clearing of the Breedts Street intersection. Observations indicated that the vehicles required approximately three minutes from joining the back of the queue to clearing the intersection during the peak 15 minutes.



Photograph 2 : Platoon arrival on departure of queue – Breedts Street

Photograph 3 indicates that the vehicles on the western approach are adversely affected by vehicle queues from intersections to the east of Breedts Street (Calliandra Street and the N1 freeway ramp terminals).



Photograph 3: Vehicle queues through Breedts Street affecting progression

9. CONCLUSIONS

The following conclusions can be made from the study:

- The travel time surveys were inconclusive as the settings were still being finalised and as a result of the changed travel pattern due to major construction work in the study area.
- The observations of arrival and departure flow patterns at intersections where the settings were applied indicated that the model provides an accurate simulation of arrival and departure patterns. The use of the model to co-ordinate traffic signals compared to traditional time-space diagrams shows promising results and should be further developed.
- Use of a common cycle length is a pre requisite for traffic signal co-ordination along arterials.
- Intersection spacing is not the only consideration for including intersections into a co-ordinated signal system, the effect of long queues (congestion) or reduction of saturation flow through the preceding intersection is also a consideration.

10. FUTURE DEVELOPMENT

- Additional research on the relationship between cycle length and saturation flow is required to provide a conclusive indication of the optimum cycle length. Other practical considerations in determining the appropriate cycle length such as the number of stages should also be addressed.
- Development of the program to also indicate arterial band-widths.
- Development of the program to accurately model the effect of short turning lanes at intersections.
- Development of the program to take short block lengths and vehicle queues through intersections into account.

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