REVISION OF THE GUIDELINES FOR ACCESS TO FILLING STATIONS IN THE GREATER PRETORIA AREA

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1. BACKGROUND

A guideline document for the provision of accesses to filling stations was prepared for the City Council of Pretoria in 1995 (1). This document was fairly comprehensive and was used for numerous filling stations in Pretoria. Several other authorities also applied this document as their standard.

Certain aspects of accesses to filling stations were however not covered well enough and needed revision. Other issues that needed to be addressed include:

- The nature and function of the convenience store has changed. To a large extent, this has replaced the "corner café" and in many cases has a similar turnover to that of the fuel side of the filling station.
- More and more convenience type, motor related services are added to filling stations. This include car wash and auto banks.
- The other land uses have been added due to access requirements - the access spacing result in many cases in a portion of land on the corner or additional land that is developed rather than left open.
- The deregulation of the fuel price is a factor that can significantly change the nature of filling stations in South Africa. Some filling stations may be forced to close down, while other may have to change the nature of their business to attract customers.

This paper briefly describes some of the aspects that were covered in the revision of the document. Specific attention is given to those elements that changed significantly in the new document.

2. DESIGN SPEED

The correct speed to use when designing the accesses to filling stations, should be the operating speed of the road. However, this is in many cases higher than the speed limit. This pose the problem that the developer of the filling station is penalized through longer deceleration lanes and larger access spacings due to the fact that drivers do not adhere to the speed limit. To simplify the design process, the speeds as shown below were recommended for different level of access classes of roads.

Level of Access	Design Speed for Access to filling station (km/h)
1, 2 and 3	80
4 and 5	70
6, 7, 8 and 9	60

3. SIZE OF THE CONVENIENCE STORE

One of the critical issues relating to filling stations, is the size of the convenience store (C-store). The present Pretoria guideline is that the size of the C-store is limited to 100 m^2. One of the objectives of the report was to investigate the possibility of increasing the size of the C-store and to determine what the impact thereof will be.

Extensive data was obtained from several sources, which provided good insight into the trip generation and other characteristics of C-stores. Surveys of 6 filling stations in Pretoria revealed the following:

- Almost 75% of the persons visiting the filling station, were pass by trips only buying fuel.
- Only 4,1 % visited the shop only - which is a very low number compared to the 13 % found in the South Trip Generation Rates (7) and the other surveys. It should be noted that in one case, a residential collector, the primary trip generation by the C-store was 29 % of the total trips.
- A total of 15,7 % of persons visiting the filling station, visited the C-store as pass by trips or combined it with refueling.
- A total of 10,4% of persons visiting the C-store combined it with refueling.
- If the size of the C-store is increased, the question is whether the 4,1 % will increase (more primary trips to the C-store) or whether the 10,4 % will increase (persons already refueling, that will buy more at the shop)

Results of a market research study done for an oil company was obtained (4). A total of 5622 respondents were interviewed at 8 different brand names of C-stores to, inter alia, determine their reasons why they visited the convenience stores. Several questions were asked relating to the popularity of the different shops, but the most relevant was the reasons why the respondents visited the convenience stores. What can be derived from these surveys are:

- 42,5 % of the persons visiting the shop did it only in emergencies, i.e. when other stores were closed and therefore out of the peak hour of the adjacent street. These trips can however be defined as primary trips to the C-store. This is significantly higher than the 13% from SA Trip Generation (7) or from the study done for the City Council (6). It is possible that the 4,1 % and the 13 % found in the latter surveys relate more to peak hours.

- 22,1 % of persons visiting the shop combined it with buying fuel or on their way to work - therefore a pass by trip.

- The remaining 35,4 % of the persons visiting the shop is difficult to define as pass by, new trips or peak hour trips, and it is assumed that these are new trips. This is only an indicative value and not absolute, as the questions were not asked in such a way to accurately determine the origin of the trip.

An empirical calculation - that is nothing more than indicative - show that if the primary trip generation by the C-store doubles, the larger C-store can generate between 16 and 40 additional vehicle trips. Whether it will in fact double, is impossible to predict and will be dependent on the nature of the adjacent street and the location of the filling station / C-store in relation to residential areas, neighborhood centres and other factors.

To determine the maximum size of the convenience store is market dependent and can not be recommended, from a traffic point of view, with the limited data available. A phased approach where the C-store size is increased incrementally will have to be followed. Current market forces are requesting a C-store where the size of the building is 250 m² and the leasable area is 180 m². This can be supported from a traffic point of view as it is expected to generate limited additional traffic.

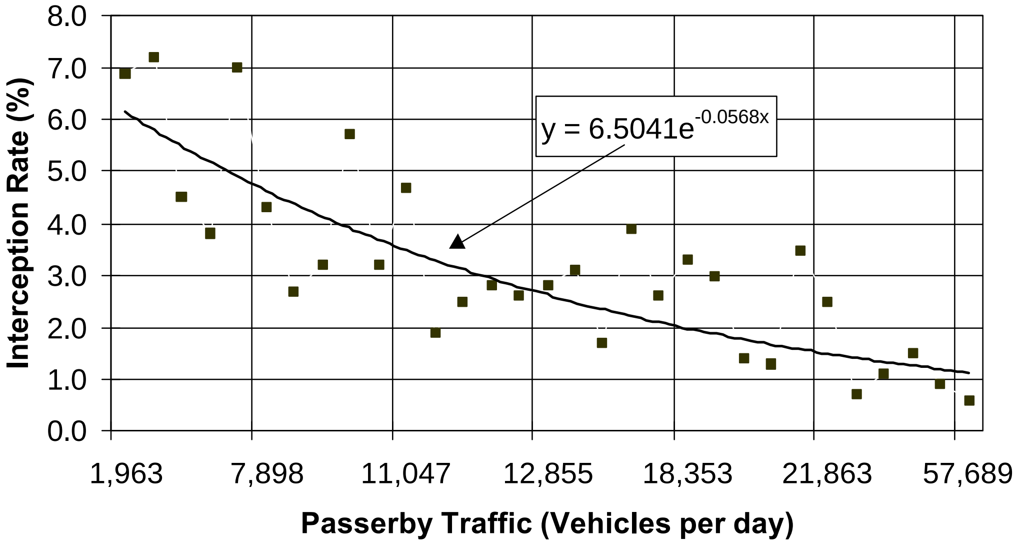
4. INTERCEPTION RATES

In the analysis of the feasibility of a filling station, the interception rate (percentage of traffic on the adjacent road that turns into the filling station) is a critical variable. It also has an implication on the operation of the accesses to the filling station as the number of potential conflict movements increase with increasing vehicles that enter the filling station.

Surveys were done at 35 filling stations (3) of varying location and with different volumes of pass by traffic.

The interception rate clearly declines with an increase in passerby traffic. The total volume entering the filling station is however higher for higher passerby volumes.

An interesting fact is that no guidelines for filling stations specify the number of pumps that should be installed - this is left to the discretion of the oil company. In the case of access booms to parking areas, it is normally required to specify the number of lanes required to serve the traffic demand at a certain service rate. If a filling station is located next to a road and has a very high interception rate, queues can form at the pumps that can affect the operation of the accesses. This has however never been a requirement before and seems to work well as no long queues were observed at any of the filling stations during normal operations.



Interception rate versus passerby traffic

5. INTERACTION WITH OTHER DEVELOPMENTS

One of the arguments used as to why filling station accesses can be located closer to intersections, is that filling stations are only interceptors of traffic. The fact that it intercepts traffic, only results in lesser additional traffic on the adjacent street network, the vehicles entering and exiting the filling station still have the same conflict movements as any other left-in left-out access or full access. The conflict movements consist of the speed differential between through and in turning traffic, as well as the exiting traffic that has to find a gap in the traffic stream.

As a comparison, if an office development, generating say 150 vehicles per hour, was provided with a left-in left-out access, the same number of conflict movements would therefore have existed regardless of the fact that there are more vehicles on the adjacent street.

The other factor that will remain the same, regardless of the type of development, is the calculation of the deceleration lane length. In the calculation of the deceleration lane length, the traffic volume and whether the entering traffic is intercepted or generated trips are not taken into account - the speed differential between through and entering vehicles is the critical variable.

There are two main reasons why other developments can possibly not be combined with filling stations, namely:

- The limiting factor that has to be accepted, is that the exit from a filling station will always have to be stop controlled. The total number of vehicles that enter a filling station typically does not exceed 80 vehicles per hour - given a 50 / 50 directional split, the total trip generation is say 160 vehicles per hour. The warrants for the erection of traffic signal in the South African Road Traffic Signs Manual (9) states that for a three legged intersection, traffic signals are typically warranted if the critical side street volume reaches 160 vph. This implies that at most filling stations, an additional 80 vehicles per hour can be generated without warranting the provision of a traffic signal for exiting traffic.

- Other developments may generate more primary trips (new trips on the road network) that want to return to their origin, resulting in possible u-turns if only left-in left-out access is provided. The filling stations therefore has to have at least one full access if combined with other developments to avoid u-turn movements.

The provision of other low traffic generators can be allowed with filling stations without having a negative traffic safety or capacity impact. Each individual case will have to be evaluated in terms of total expected trip generation and trip distribution to determine if a traffic signal will be warranted and if u-turns will be a critical factor.

This proposal is in line with the Road Access Policy of the Western Cape (11), which specifies "Petrol service stations are no different from other convenience type retail or commercial enterprise which facilitates drive in service." . . . . . "the guidelines do not provide any special recognition of one land use type over that of another".

Given the limitations on the type of development, the trip generation and the other criteria, limited additional facilities can be provided on site with the filling station.

At the time of writing this paper no final decision has however been taken on this issue.

6. PROVISION OF A MEDIAN ISLAND

The existing warrants in the Pretoria guidelines (1) is that a median barrier is required on all class B and D roads, except in exceptional cases or on one-ways.

The current Gautrans standard, BB2 (12) is that if a road carries above 6000 vehicles per day, a median is required. This is based on capacity analyses of the access, allowing for a certain percentage of traffic that will occur during the peak hour, a interception rate and also allows for future growth in traffic.

The problem with a volume based warrant is that on most roads where a filling station is viable, the traffic will increase at some stage to a level where it will require a median to prevent right-turns. This will require an agreement between the developer or land owner and the City Council that once the traffic volume warrants it, a median should be provided. Experience has shown that this is difficult to implement in practice as it is difficult to enforce after sometimes several years where there may be new owners of the specific filling station.

A warrant based on the classification of the road is easier to implement and prevent the marginal cases where if the volume is 5900 a median is not required, but if it is 6050 vehicles per day, a median is required.

The recommendation is therefore that a median should be provided on all undivided roads that have level of access classification of 1, 2, 3, 4 and 5.

7. ACCESS TO FILLING STATIONS - RESULTS OF FIELD OBSERVATIONS

Entrances to filling stations consist of either left-in entrances from major roads or full entrances with right-in movements allowed. The full accesses are typically on lower order roads and should be provided with a right turn lane where the traffic volume warrants it.

The following is a summary of the main observations that were made on the entrances to filling stations - what work, what does not work and what shortcomings exist.

a) **Deceleration lanes:** The general observation at filling stations was that deceleration lanes are provided in many areas, with adequate length, but due to poor detail design there effectiveness are significantly reduced. The elements that reduce the effectiveness of them are given below.

b) **Passive taper rate**. Several filling stations were observed where the taper rate is less than 1:10. This only result in a triangle where sand and rubble lies around and a place where taxis can park to offload passengers. The purpose of the taper and deceleration lane is reducing speed differential - observations revealed that vehicles follow a horizontal curve when entering the filling station which corresponds more to a 1:10 taper - providing anything less, results in the unused triangle. Shorter tapers can function at intersections for right turn lanes, but serve no purpose for deceleration.

c) **Taper breakpoint**. The shape of the taper breakpoint is important. This is the point where the taper or the deceleration lane starts. It was observed that if this point is formed by high standing vertical kerbs, people tend to try and avoid it and effectively reduce the length of the deceleration lane. The taper breakpoint is at the junction of kerbs and this sometimes result in slightly higher kerbs which gives motorists the perception that they should steer away from it. A possible change is to provide a yellow line breakpoint, but the taper and the normal kerb line should join with a small radius.

d) **Width of deceleration lanes**. The width of the deceleration lane plays an important role. The previous guidelines recommended a minimum of 2,7 m. This was observed to be too narrow. It was not specified from where to where the 2,7 m should be measured - from the front of the kerb, from the centre or the inside of the yellow line - this can result in a difference of up to 400 mm in effective lane width if a 300 mm channel section is provided in front of the kerb. The deceleration lane - if a lane is provided together with the taper - should be a minimum of 3m wide between the yellow line in front of the kerb and the white line.

e) **Entry radius**. The entry radius can make or break the effectiveness of the deceleration lane. Ideally the entry radius should be 15m.

f) **Joining of the deceleration lane to the existing road surface**. This is again the detail which are not normally addresses in access guidelines, but result in poor operations if not designed correctly.

The cost of deceleration lanes in many cases result in developers using paving blocks to build the deceleration lane in stead of asphalt. The deceleration lane should be flush with the existing lane and should ideally have the same crossfall as the existing road.

8. SPACING OF DOWNSTREAM FILLING STATION ENTRANCES

The criteria for determining the location of the entrance to a filling station, is the minimum distance downstream from an intersection, and this is based on the required deceleration lane length. The reason for this is that the deceleration lane should not extend through the upstream intersection. The following criteria are typically used for the location of the downstream filling station:

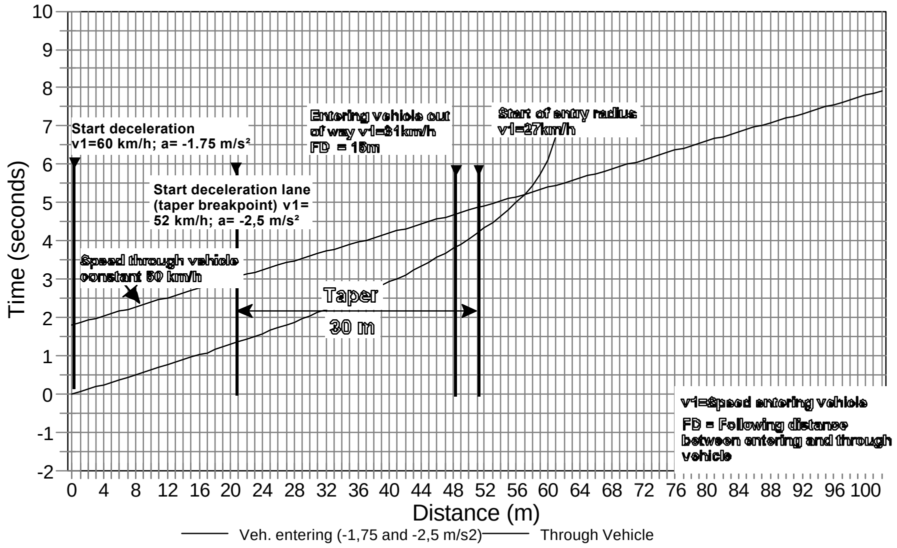
- deceleration length
- shoulder sight distance for vehicles exiting from the filling station.

The provision of deceleration lanes at access points to reduce speed differential is an accepted principle and the field surveys showed that where well designed deceleration lanes exist, they do reduce conflict.

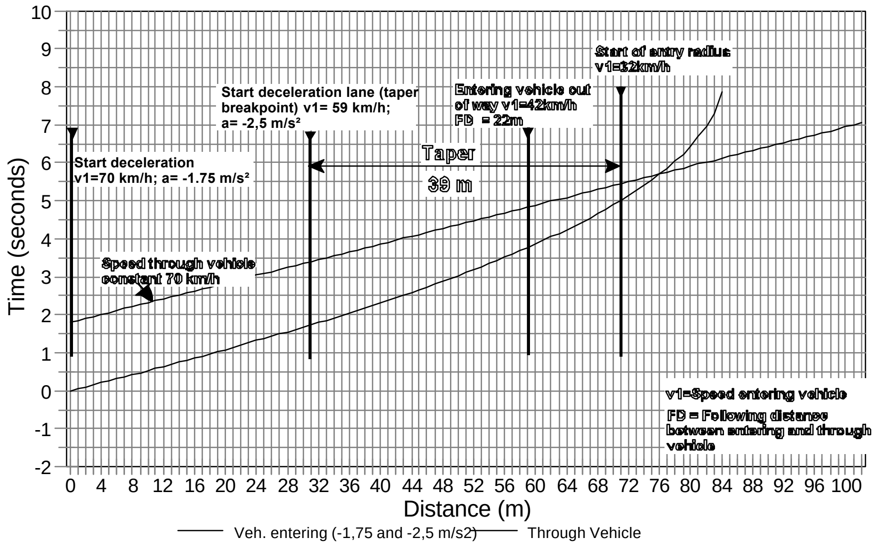
Lessons learned from field observations: Deceleration is generally assumed to be constant. However, there was a clear difference observed in the way vehicles approach an access. There is an initial deceleration while the entering vehicle is still in the through lane - the driver typically removes his foot from the accelerator pedal, but does not always start braking. The accurate determination of this will require extensive research and assumptions had to be made to allow for this phenomenon. It was assumed that a driver will typically make the decision to enter the filling station 1 to 1,5 seconds before the taper brake point. This has an impact on the required deceleration lane length, as the speed of the vehicle as it enters the deceleration lane is then lower. The 1 to 1,5 second is selected based on observations at filling stations and is a mere approximation.

Deceleration rates for the determination of deceleration lane lengths was studied and various sources were consulted to select an appropriate deceleration rate.

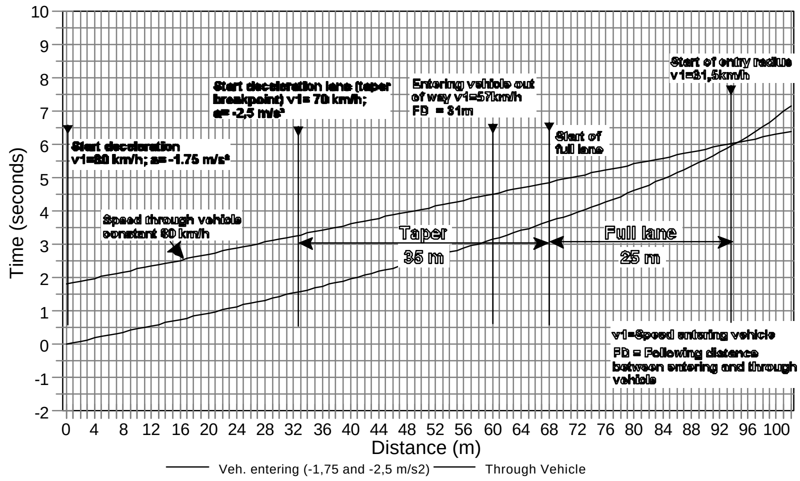
The calculation of the deceleration lane length is shown in the figures below.



Time - Space diagram indication speed differential (60 km/h)



Time - Space diagram indication speed differential (70 km/h)



Time - Space diagram indication speed differential (80 km/h)

9. SPACING OF UPSTREAM FILLING STATION ENTRANCES

9.1 Existing Pretoria Guidelines

The existing guidelines (1) recommend that upstream filling station accesses be located at the following distances from the closest erf boundary to the far side kerb of the filling station access:

60 km/h:	35 m
70 km/h:	45 m
80 km/h:	60 m

These distances are significantly lower than the distances recommended in the BB2 document (12) for example and specific attention was paid to the operation of these accesses during field observations.

9.2 Field observations

The fact that the existing guidelines are at a lower standard than prescribed in other guidelines, required specific observations at the exits from filling stations.

The reason for the longer spacing used in other guidelines is to allow the driver to observe the accesses one at a time. What was found in the field, is that drivers do not drive and consciously observe one access after the other. It was found with the observations that most drivers of through vehicles are more affected by the entrance to the filling station, especially if the deceleration is of a poor design. After passing this, there focus is normally on what happens at the intersection and not on the filling station exit.

The BB2 document of Gautrans (12) use stopping sight distance to determine the spacing of upstream accesses to filling stations. These recommended distances do however result in long distances from intersections and will require the filling station over several erven.

9.3 Stopping Sight Distance

One of the concepts used in most access guideline documents, is that stopping sight distance should be available between two intersections to allow the driver to observe the intersections as separate decision points. This stopping sight distance is normally measured from the side of the crossing road to the side of the adjacent exit or intersection. The reason for this assumption, is to allow the driver of the through vehicle adequate time to stop should a vehicle enter the traffic stream at the intersection or access.

The following table shows typical values of stopping sight distances for different speeds.

STOPPING SIGHT DISTANCE

Speed (km/h)	f (friction factor)	Effective deceleration rate (m/s^2)	Perception reaction distance (m) *(0,7 v)*	Braking distance (m) *(v^2 / 254 f)*	Stopping Sight distance (m)
60	0.32	-3,63	42	44	86
70	0.31	-3.14	49	62	111
80	0.30	-2,94	56	84	140

Note: The 85 th percentile speed is normally used to calculate the stopping sight distance - in this case the speed limit is used as this is used as the design speed.

9.4 The applicability of stopping sight distance as a criteria for the spacing of accesses

The behavior of the driver when driving along a road is of critical importance when deciding on the spacing of accesses. The driving task, as described in the SA Road Safety Manual (17), consist of several tasks and is quoted here below.

The driving task consists of three components, namely:

- *Navigation – Route following and trip planning*
- *Guidance - Following the road and keeping a safe path in response to the traffic conditions*
- *Control – Speed control and steering.*

<u>The process of the driving task</u>

The driving task requires the following process:

- *The driver receives input (mostly visual)*
- *The driver processes the information*
- *The driver predicts the outcome of alternative actions*
- *The driver decides on the appropriate action and execute them*
- *The driver observes the effect of the actions through reception and processing of updated information*

To further understand the behavior of drivers and the functioning of the human vision in relation to driving actions, discussions were held with a bio engineer at the University of Pretoria, (18). Although the knowledge obtained through this discussion was not directly applicable, it improved the understanding of the issue.

A driver has *peripheral vision* and *focal vision*. Peripheral vision is what the human eyes see in the total cone of vision (based on the SA Road Traffic Sign Manual (9), this is 15 degrees to each side, i.e. 30 degrees). Any movement or change in this peripheral area is picked up by the eye and interpreted by the brain, although the eyes are not focused on the object specifically. This allows the driver to observe the whole road reserve in front of him, while focusing on the vehicle he is following or on the color of the traffic light, for example. *Focal vision*, which has a width of about 1 degree, is used to read road signs, focus on specific objects, to judge distance etc.

The use of peripheral vision explains why a driver on a busy street like Pretorius Street, with numerous direct accesses, can retain following distance from the vehicle in front, read the advertisement on the lamp post, observe the color of the traffic light and see the vehicle that is about to enter from the home office (of which there are accesses every 50 m). The driver does not focus on access after access as he drives along, he merely observes with peripheral vision the whole road reserve or area that is required to steer safely and react on changes in that area.

This brings a further factor into play - a driver react differently to accesses when driving alone at a desired speed on a road versus when following another vehicle. If the driver is following a vehicle, his focal vision is mostly on the vehicle he is following as this presents the critical braking scenario. Peripheral vision is then used to pick up other information such as accesses, road signs etc., and if necessary, the focal vision is shifted to these areas to interpret the information.

The vehicle driving at desired speed alone or in front of a platoon presents the critical scenario for the evaluation of access spacing. This vehicle has to observe the intersections in front for conflicting traffic. The critical movement is not so much traffic from the side road, but the vehicle standing in the intersection waiting for a gap to turn right. These vehicles often take a short gap and force oncoming to traffic to reduce speed or stop.

The difference between a vehicle in front of a platoon and a vehicle that is following other vehicles, is that their sight distance differ significantly. The vehicle in front's sight distance is not reduced by other vehicles, he can typically see beyond the intersection. Drivers tend to observe the whole road in front of them if they are driving in front - typically 200 to 300 m ahead of them or as far as the geometry of the road allows.

The above table shows the two components of stopping sight distance - perception distance and braking distance. The braking distance for each of design speed is longer than the perception distance.

The summary of the above reasoning, is that accesses can be placed perception sight distance apart to allow the driver adequate time to observe each access or intersection. The driver (not following other vehicles) will always observe the access with stopping sight distance available, but after perceiving the access, can move his focus or perception to the next access. An access can therefore be placed approximately halfway of the stopping sight distance - in the case of 60 km/h the perception and braking distance is almost equal.

This reasoning is the best explanation found for the fact that the existing Pretoria guidelines (1) work in practice, as the spacing recommended previously are very similar to perception sight distance, although derived from a completely different basis. The previous spacing of upstream intersections was taken as a value that represents a “sort of average” of all the different criteria of other cities and is not based on theory.

The further point that support this reasoning, is that the perception distance is very similar to the deceleration distance. Between two accesses the minimum spacing will also be determined by the length of the deceleration lane necessary to avoid conflict with through traffic - given the principle that the deceleration lane for one intersection should not extend through the next.

If the different distances for the location of upstream accesses are compared, a range of different values are found, as shown in the table below.

LOCATION OF UPSTREAM ACCESS BASED ON DIFFERENT CRITERIA

Speed (km/h)	Stopping Sight distance* (m)	Functional Boundary Distance	Existing Pretoria Guidelines	Perception Distance**	Deceleration distance (m) ***
60	80	130	40	42	50
70	95	160	50	49	60
80	115	200	65	56	80

* As given in UTG 1 (14), based on 85 th percentile speed.
** Based on a perception time of 2,5 seconds and the speed of the road
*** The deceleration distance is approximated from the nearest kerb of the intersecting street to the point on the entry radius where the filling station is entered. Refer to Appendix C for precise measuring points.

As reasoned in previous sections, stopping sight distance and functional boundary distance are not seen as suitable criteria for the spacing of upstream intersections. The largest of the perception distance and the deceleration distance should be taken, which is the latter. The deceleration distance, with the values outlined in the table above, is therefore recommended as the spacing of the upstream accesses.

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