INTERSECTION SAFETY: A TSHWANE CASE STUDY

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ABSTRACT

The Safe System Approach (SSA) advocates for a forgiving and self-explaining roads and covers aspects such as safer vehicles, safer speeds, safer roads, post-crash care and safer people. The principles that SSA incorporates are zero tolerance for death and serious injuries, human error is inevitable, human vulnerability, shared responsibility, proactive interventions for safety, and redundancy of the transport system.

This case study considers road safety aspects at a specific intersection in the City of Tshwane. The study made use of observations and traffic conflict modelling tools to assess intersection safety.

Effective planning of intersections is essential in transportation and road safety engineering. Intersections are critical junctions in the road network where various traffic flows converge and where the potential for traffic conflicts is higher. The intersection design significantly influences safety, traffic movement, and the overall efficiency of the road system.

It has been observed that when vehicles approach the full access intersection (T-junction) to make a right turn, drivers experience restricted visibility of oncoming traffic from the right due to parked vehicles along the roadside. This configuration forces drivers to advance cautiously into the oncoming traffic lanes to gain a clearer line of sight, leading to unsafe turning manoeuvres and traffic conflicts. Additionally, these vehicles are required to queue within the intersection between the traffic islands, while waiting for a safe gap from the oncoming traffic from the left to complete their turn and merge onto the lane after making the turn. This operational challenge raises concerns regarding the potential need for a traffic signal or a general intersection upgrade at the intersection, or similar intersections with comparable safety and flow issues. This paper concludes with recommendations to address safety concerns at this intersection type aligned with the Safe System Approach.

Keywords: Safe System Approach, Road safety engineering, Intersection safety.

1. INTRODUCTION

1.1 Background

The Safe System Approach advocates that the design of the road should be forgiving and self-explaining (Tingvall et al., 2000). Traditionally, intersections often present numerous conflict points where traffic paths intersect, increasing the potential for collisions. A study

published in the Transportation Research Record introduced the Safe System for Intersections (SSI) method, which integrates Safe System principles into intersection planning and design. This method provides a framework for evaluating intersection designs based on their potential to reduce fatal and serious injury crashes (Cadappa et al., 2015). The research emphasised that traditional intersection designs often prioritise vehicular capacity over safety, whereas designs adhering to Safe System principles focus on reducing conflict points and managing vehicle speeds to enhance overall safety.

Effective planning of intersections is essential in transportation and road safety engineering. Intersections are critical junctions in the road network where various traffic flows converge and where the potential for traffic conflicts is higher. The intersection design significantly influences safety, traffic movement, and the overall efficiency of the road system.

1.2 Aim of Paper

This research aimed to assess and evaluate road safety concerns at a specific intersection in the City of Tshwane, primarily focusing on the restricted visibility and unsafe turning manoeuvres that occur at a specific T-junction. This case study intends to:

- Identify the traffic safety issues associated with the design of the intersection, taking into consideration the impact that parked vehicles have on the driver's ability to see oncoming traffic.
- Evaluate the operational challenges resulting from the current layout of the intersection which affects the traffic flow and likelihood of accidents.
- Explore solutions aligned with the Safe System Approach by recommending potential upgrades.

1.3 Problem Statement

The safety of the T-junction intersection in the City of Tshwane is compromised due to limited visibility, primarily caused by parked vehicles along the roadside. This reduced visibility forces drivers to cautiously move into oncoming traffic lanes to obtain a clearer view of the road. The posted speed limit of the road is 60 km/h in this specific section. However, the speed limit on the rest of the R104 varies between 60 km/h and 80 km/h on other sections of the road. Drivers entering into the intersection must participate in unsafe turning movements to turn into or over the intersection. These unsafe actions increase the likelihood of traffic conflicts. The driver's line of sight is restricted due to the parked vehicles, as seen in Figure 1.

Furthermore, as shown in Figure 2, vehicles are often required to wait within the intersection, typically aligned with the median, for an adequate gap in traffic to complete their turn. This action heightens the safety risks and disrupts the flow of traffic. These operational challenges highlight the urgent need for an intersection redesign or the introduction of traffic control measures to improve both safety Level of Service (LOS) and efficiency.

Figure 1: Drive's line of sight at the intersection

Figure 2: Expected right turn movement through the intersection

1.4 Scope of Study

This paper focuses on the intersection of Buckle Road and Pretoria Street (R104) as a case study of road safety risks at a full-access intersection. The intersection is in Silverton, an eastern suburb of Pretoria. Pretoria Street classifies as a Class 2 Major Arterial and Buckle Road feeds traffic to office buildings, retail shops, restaurants, and shopping malls in the vicinity. There are several similar intersections in the Silverton suburb where a case

study like this would be useful in assessing the road safety concerns due to the traffic conflicts.

The study aims to evaluate the operational challenges resulting from this visibility issue and propose possible improvements in line with the Safe System Approach to enhance road safety. In addition, the following criteria determined the scope of the paper:

- **Geographical location**: The research is limited to the analysis of a single T-junction intersection situated at the corner of Buckle Street and Pretoria Road (R104) in the Silverton suburb of the City of Tshwane. The study does not extend to other intersections in the city or region.
- **Methodology**: The study primarily relied on observational data and the use of traffic conflict modelling tools.

1.5 Study Limitations

The study is limited to a single intersection and mainly focuses on driver safety and does not account for other vulnerable road users such as pedestrians and cyclists.
The traffic count was conducted from a 5-minute traffic spot count which was then interpolated into hourly count during peak duration, however, a longer duration would aid in obtaining accurate traffic volumes on the intersection.

The findings and recommendations apply specifically to the T-junction under study and may not directly translate to other types of intersections without further investigation.

2. METHODOLOGY

2.1 Intersection Sight Distance

The video data was collected with a Garmin 57© dashcam installed onto the dashboard of a moving vehicle. The driver drove around the intersection to record the interaction of traffic and record visibility issues that a driver would typically experience in this intersection. Secondly, a stationary video camera was used to capture traffic movements in the intersection. This perspective was filmed from a stationary point of view using a cell phone camera. The video footage was then analysed through observation to extract the relevant parameters of the road intersection and the traffic as inputs required for the traffic modelling tools. Video footage was collected over three days and consisted of morning peak, midday peak and afternoon peak observations.

Intersection sight distance is the distance at which a driver, stopped at a stop-controlled intersection, and can see approaching vehicles. This allows the driver to perform one of three operations before the vehicle reaches the intersection. The sight distance applies even if the approaching vehicle only becomes visible after the driver has stopped (CSIR, 2000).

The three operations are defined as follows:

- Turn to the left in advance of a vehicle approaching from the right.
- Turn to the right, crossing the path of a vehicle approaching from the right and in advance of a vehicle approaching from the left.
- To move across the major highway in advance of a vehicle approaching from the left" (CSIR, 2000).

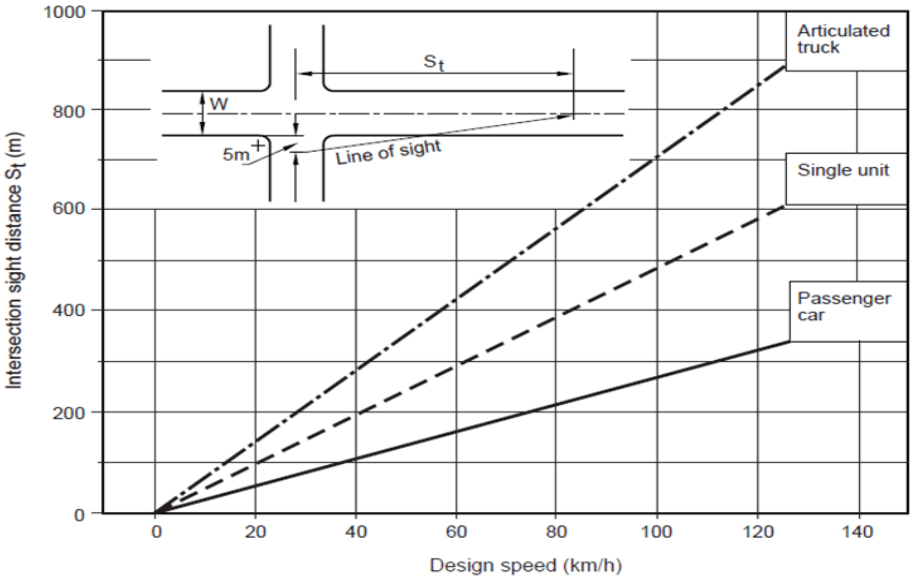

Figure 3: Intersection distance (CSIR, 2000)

As shown in Figure 3, the intersection sight distance is calculated based on the road's design speed of 60 km/h. This calculation allowed us to determine the required intersection sight distance, which will be discussed in more detail later. The actual intersection sight distance was then drawn to scale in AutoCAD, georeferenced, and overlaid on Google Earth maps for illustrative purposes.

2.2 Traffic Conflict Mitigation Tool

The Traffic Conflicts Mitigation Tool is a tool being developed by the Council for Scientific and Industrial Research (CSIR) Smart Mobility research team and will be used to analyse and assess the safety and performance of road intersections, especially in terms of traffic flow and potential conflict points between vehicles. The Traffic Conflict Mitigation tool focuses on identifying areas where vehicles may face delays or increased risks of accidents due to congestion, poor geometry, or interaction with other road users.

The tool typically calculates:

- Volume-to-Capacity (v/c) Ratios: Measures how much traffic flows through an intersection compared to its design capacity, which helps in identifying congestion levels.
- Delay Calculations: Estimates the waiting time of vehicles at an intersection due to traffic conflicts or congestion.
- Level of Service (LOS): A grading system that categorises the performance of the intersection based on delay times (A to F, with A being optimal and F indicating failure).
- Accident Probability: Estimates the likelihood of accidents at the intersection based on traffic volume and congestion levels.

The Traffic Conflict Mitigation tool is being developed to understand traffic behaviour, identify conflict areas, and make recommendations for improving intersection safety and efficiency.

2.3 Sidra Analysis

SIDRA Intersection is a widely used micro-analytical traffic modelling software designed for the operational analysis, capacity assessment, and performance evaluation of signalised and unsignalised intersections. It provides detailed computations of intersection performance measures, including delay, queue lengths, LOS, and degree of saturation for different movements and approach lanes. The SIDRA Intersection was used in this analysis to provide comparative results for the Traffic Conflict Tool, which is currently under development by the CSIR. The primary objective was to validate the intersection performance results produced by the tool, ensuring alignment with established traffic analysis methodologies. Furthermore, SIDRA was utilised to explore alternative intersection configurations that the Traffic Conflict Tool cannot currently model, particularly a partial intersection (left-in, left-out configuration).

2.4 Data Collection and Processing

To assess the operational performance and safety implications of various intersection control strategies at the R104 Pretoria Rd and Buckle Rd, intersection traffic data was collected during the afternoon peak period. A 5-minute spot count was conducted and subsequently extrapolated to estimate hourly flow rates for analysis. A Peak Hour Factor (PHF) of 0.85 was applied, based on the assumption of moderate traffic fluctuations within the peak hour, which is typical for Central Business District (CBD) areas. Figures 4 and 5 below show the estimated traffic parameters per traffic direction and the overall estimated traffic parameters of the intersection, respectively.

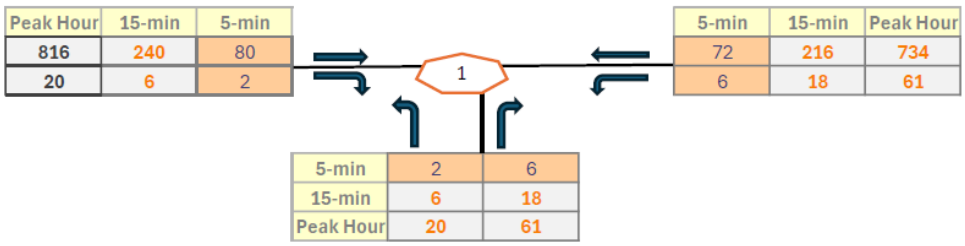

Figure 4: Estimated traffic parameters per traffic direction

Road	Hourly Flows (vph)
Pretoria St	1632
Buckle Rd	82

Figure 5: Overall estimated traffic parameters

2.5 Intersection Control Alternatives Evaluated

The existing priority stop-controlled intersection shown in Figure 6 below was analysed using SIDRA Intersection software, along with three alternative configurations, namely, signalised control, traffic circle (roundabout), and a partial intersection (Left-in, Left-out). A layout of the existing intersection is shown below.

Each intersection control scenario was modelled in SIDRA Intersection 7.0 software using the estimated hourly traffic volumes, PHF adjustments, and intersection geometry data. The intersections were evaluated based on their v/c, delay, and LOS similar to the tool.

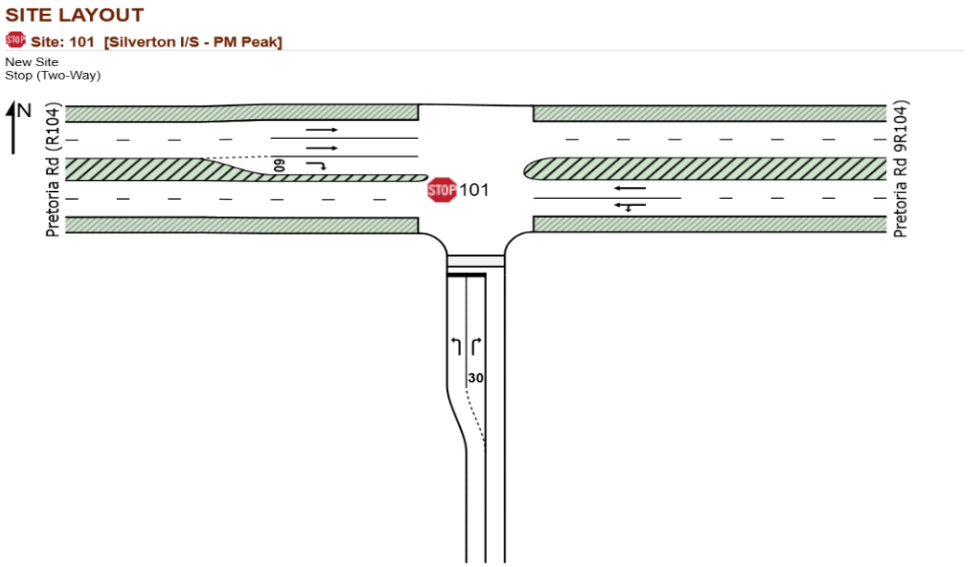

Figure 6: R104 Pretoria Rd and Buckle Rd intersection layout

3. RESULTS AND DISCUSSION

3.1 Intersection Sight Distance

As seen in Figure 7 below, the required intersection sight distance was found to be 160m, thus confirming that the current intersection layout does not meet the requirements due to vehicles on the parking bay obscuring the driver's line of sight. To improve the driver's line of sight, 27m of parking bay would have to be removed.

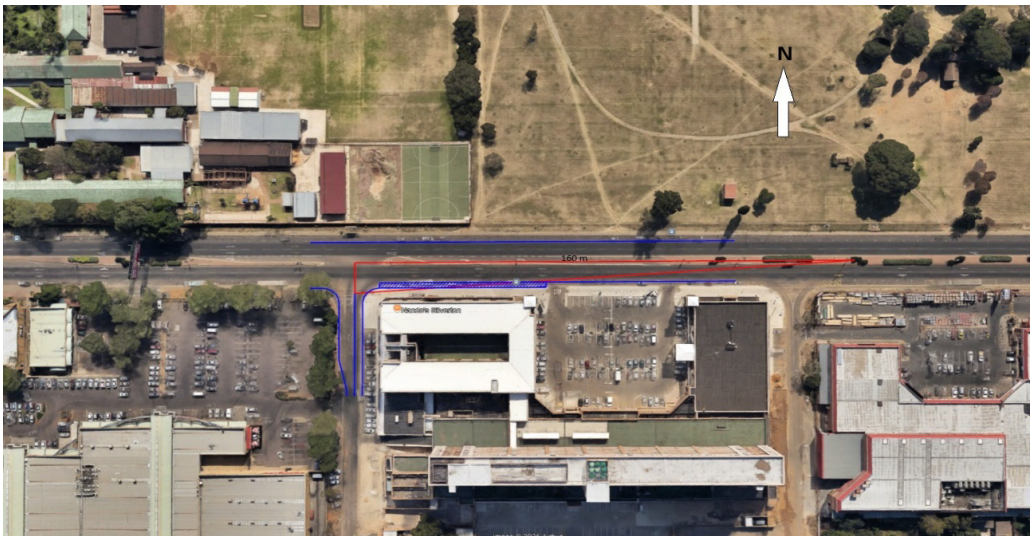

Figure 7: Google Earth image of Pretoria Rd & Buckle Rd with sight distance configuration

3.2 Impact of Sight Distance on Driver Behaviour and Road Safety

Sight distance is a critical factor in intersection safety, as it determines a driver's ability to perceive, assess, and respond to gaps in traffic. The presence of parked vehicles along the R104 Pretoria Road obstructs the line of sight, making it difficult for drivers on Buckle Street to judge the speed and distance of approaching vehicles. As a result, drivers are forced to edge forward beyond the stop line to gain better visibility, exposing the front portion of their vehicles into the travel lanes before they have the necessary clearance to safely execute a turn.

From the observations (speed was not quantified or measured), it seems that Pretoria Road may be characterised by higher than the posted (60km/h) vehicle speeds, which further exacerbates the problem. When vehicles travel at higher speeds, the required stopping sight distance increases, meaning that drivers have less time to react to unexpected obstructions.

3.3 Analysis of Existing Priority Stop Intersection

The intersection is currently a priority stop-controlled junction, with Pretoria Rd acting as the major road and Buckle Rd as the minor road. To check and validate the Traffic Conflict and Mitigation Tool's outputs, a parallel SIDRA intersection analysis was conducted. The study evaluated the existing priority stop configuration, and three alternative intersection designs, namely, signalised intersection, roundabout as well as a partial intersection configuration (Left-in, Left-out). A layout of the existing intersection configuration is provided in Figure 4 above.

3.3.1 Existing Intersection With TCM Tool

Table 1 shows the current performance of the priority stop-controlled intersection at Pretoria Road (major road) and Buckle Road (minor road). The data reveals congestion, as indicated by the high v/c ratios. The northbound right turning movement experiences a delay of 90 seconds with a Level of Service (LOS) of "F", indicating severe congestion. The eastbound movement has a v/c ratio of 0.5715 and a LOS of "A", reflecting minimal delay. The westbound movement has a v/c ratio of 1.5, a delay of 22.5 seconds, and a LOS of "C", indicating moderate congestion. The comprehensive accident probabilities vary, with the highest risk observed for the northbound movement (0.2), while the eastbound and westbound movements have lower probabilities of 0.015 and 0.04, respectively. Overall, the intersection exhibits operational inefficiencies and potential safety concerns.

The comprehensive accident probabilities were calculated using this formula:

$$CAP = (Wvc * Rear\ End\ Collision\ Probability) + (Wdelay * Side\ Swipe\ Collision\ Probability) + (Wroad * Road\ Conditions)$$

- Wvc: Weight for the contribution of rear-end collisions based on the v/c ratio (volume-to-capacity ratio). Higher congestion increases rear-end collision risk.
- CAP: Comprehensive Accident Probability.
- Wdelay: Weight for the contribution of side-swipe collisions influenced by the delay at the intersection. Longer delays increase the likelihood of risky manoeuvres, such as sideswipes.
- Wroad: Weight for the effect of road conditions on accident risk. Poor road conditions (e.g., potholes, lack of signage) contribute to higher accident probabilities.

Table 1: TCM Tool results for existing intersection

Movements	***v/c Ratio***	***Delay (seconds)***	***Level of Service (LOS)***	***Comprehensive Accident Probability***
Northbound	6	90	F	0.27
Eastbound	0.5	15	A	0.015
Westbound	1.5	22.5	C	0.04

3.3.2 Existing Intersection With SIDRA

The SIDRA results provide insight into how different control measures impact intersection safety and efficiency, particularly through LOS and delay times. Table 2 below shows the results of the existing priority stop intersection. The traffic movement at the intersection is characterised into three types; northbound for traffic flowing from top to bottom (this is the Buckle St (approach), westbound for traffic moving from east to west on Pretoria St, and eastbound for traffic moving from east to west on Pretoria Rd.

Table 2: SIDRA results for existing intersection

Traffic Type	*V/C Ratio*	*Delay (seconds)*	*LOS*
Northbound	3.23	850	F
Westbound	0.24	0.5	A
Eastbound	0.25	0.3	A
Total for Intersection	**3.23**	**40.5**	**E**

The results for the existing priority stop intersection highlight severe operational inefficiencies, particularly for the minor road (northbound approach), which experiences a critical V/C ratio of 3.23, extreme delays of 850 seconds (14.2 minutes). In contrast, the major road (Pretoria Rd, westbound and eastbound traffic flow) operates under free-flow conditions, with V/C ratios of 0.24 and 0.25, minimal delays of 0.5 and 0.3 seconds, and LOS A. The imbalanced LOS between the major and minor roads suggests that the priority stop control may be inadequate for the traffic demand.

3.4 Analysis of Signalised Intersection

A signalised intersection was evaluated as an alternative option for improving service levels and safety at the intersection. The layout of this alternative is provided in Figure 8.

According to the South African Road Traffic Signs Manual (SARTSM), a signal warrant study must be conducted to determine whether signalised control at an intersection is justified (Department of Transport, 1999). However, this assessment falls outside the scope of this paper. For the purposes of this analysis, it is assumed that signalisation is warranted.

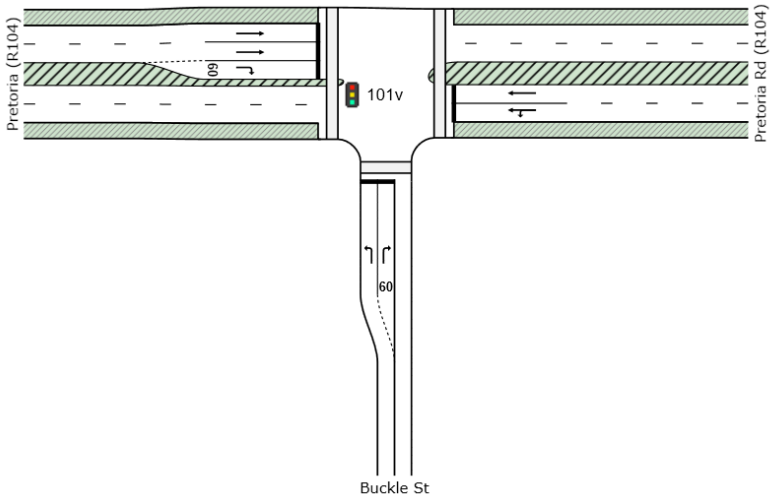

Figure 8: Signalised intersection layout

3.4.1 Signalised Intersection With TCM Tool

Table 3 presents the v/c ratios, delays (in seconds), level of service (LOS), and comprehensive accident probabilities for each movement at the intersection, where Pretoria Road remains the major road and Buckle Road is the minor road should the intersection be signalised.

- The northbound movement has a v/c ratio of 1.11, experiencing a delay of 33.33 seconds and a LOS of C, with an accident probability of 0.021.
- The eastbound movement has a v/c ratio of 5.4, reflecting severe congestion with a delay of 163.64 seconds and a LOS of F, accompanied by a high accident probability of 0.240.
- The westbound movement has a v/c ratio of 5.4, experiencing a delay of 163.64 seconds and a LOS of F, with an accident probability of 0.240.

While the proposed signalised section reduces some congestion compared to the existing priority stop-controlled intersection, several movements still face long delays and operate at a poor LOS (F). Accident probabilities remain high for the most congested movements.

Table 3: TCM Tool results for signalised intersection

Traffic Type	*v/c Ratio*	*Delay (seconds)*	*Level of Service (LOS)*	*Comprehensive Accident Probability*
Northbound	1.11	33.33	C	0.021
Eastbound	5.45	163.64	F	0.24
Westbound	5.45	163.64	F	0.24

3.4.2 Signalised Intersection With SIDRA

The results of the SIDRA signalised intersection option are presented in Table 4.

Table 4: SIDRA results for signalised intersection

Traffic Type	*V/C Ratio*	*Delay (seconds)*	*LOS*
Northbound	0.24	26.8	C
Westbound	0.60	16.0	B
Eastbound	0.62	15.7	B
Total for Intersection	**0.62**	**16.4**	**B**

The SIDRA analysis of a signalised control alternative at the intersection demonstrates a significant improvement in operational performance compared to the existing priority stop. The northbound movement (Buckle Rd), which previously suffered from LOS E with extreme delays, improves to LOS C with a reduced delay of 26.8 seconds, significantly enhancing minor road access.

The major road (Pretoria Rd) operates at LOS B, with V/C ratios of 0.6 and 0.62 and delays of 16.0 and 15.7 seconds, respectively, maintaining acceptable efficiency. Overall, the intersection achieves LOS B, with an average delay of 16.4 seconds, balancing throughput and improving accessibility for all approaches. This configuration significantly reduces gap acceptance risks and conflicting movements, enhancing safety and traffic flow stability while slightly increasing delays for the major road.

3.5 Analysis of Roundabout (Traffic Circle) Intersection

A roundabout intersection was evaluated as an alternative option for improving service levels and safety at the intersection. The layout of this alternative is provided in Figure 9.

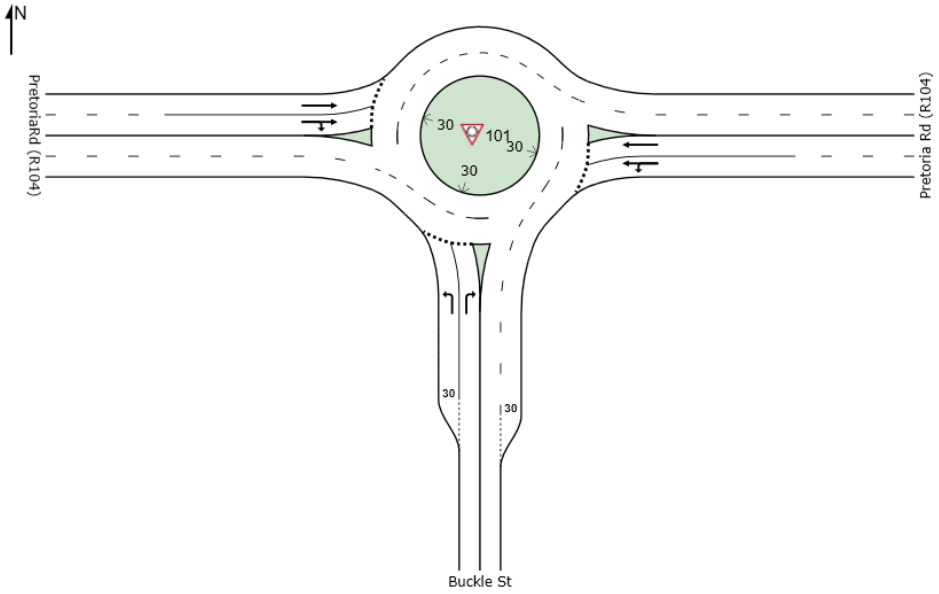

Figure 9: Roundabout intersection layout

3.5.1 Roundabout With TCM Tool

Table 5 indicates the capacity calculation results for a proposed roundabout at the intersection, with Pretoria Road as the major road and Buckle Road as the minor road. Here's a summary of the performance metrics for each movement at the proposed roundabout:

- Southbound: The v/c ratio of 0.41 is quite low, indicating minimal congestion. The delay of 15 seconds is reasonable, and the LOS of B shows good traffic flow. The accident probability is also very low at 0.014, suggesting relatively safe movement.
- Northbound: The v/c ratio of 0.45 and delay of 4.15 seconds show an excellent flow, with a LOS of A, indicating near ideal conditions. The accident probability is very low at 0.01.
- Westbound: The v/c ratio of 0.03 is extremely low, indicating almost no congestion. The delay of 7 seconds is minimal, and the LOS of A suggests excellent traffic flow. The accident probability remains low at 0.01.

Table 5: TCM Tool results for roundabout intersection

Traffic Type	***v/c Ratio***	***Delay (seconds)***	***Level of Service (LOS)***	***Accident Probability***
Northbound	0.45	4.15	A	0.01
Eastbound	0.41	15	B	0.014
Westbound	0.03	7	A	0.01

3.5.2 Roundabout With SIDRA

Table 6 shows the results of the traffic circle analysis on SIDRA.

Table 6: SIDRA results for traffic circle option

Traffic Type	*V/C Ratio*	*Delay (seconds)*	*LOS*
Northbound	0.07	9.8	A
Westbound	0.30	3.6	A
Eastbound	0.34	3.9	A
Total for Intersection	**0.34**	**4.1**	**A**

The SIDRA analysis of a roundabout indicates optimal operational performance, with all approaches achieving LOS A and minimal delays. The south approach (Buckle Rd) experiences a delay of 9.8 seconds with a low V/C ratio of 0.07, while the east and west approaches (Pretoria Rd) have delays of 3.6 and 3.9 seconds, with V/C ratios of 0.30 and 0.34, respectively. The intersection-wide LOS remains A, with an overall delay of just 4.1 seconds, marking a drastic improvement over the existing priority stop configuration. The low congestion levels and smooth traffic progression suggest that a roundabout would enhance safety by reducing severe conflict points, improving traffic flow, and eliminating excessive queuing.

3.6 Analysis of Partial Intersection

A roundabout intersection was evaluated as an alternative option for improving service levels and safety at the intersection. The layout of this alternative is provided in Figure 10.

Note: The Traffic Conflicts Mitigation Tool excluded the partial intersection analysis since the tool has not yet been developed to analyse this type of intersection.

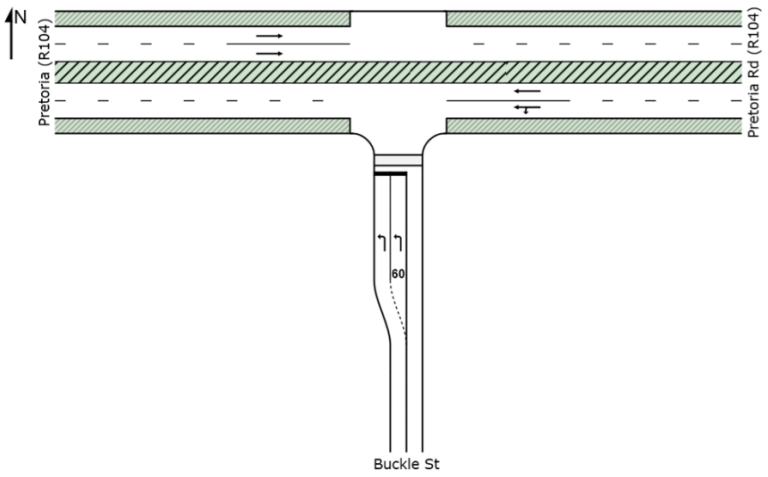

Figure 10: Partial intersection (left-in, left-out) layout

3.6.1 Partial Intersection (Left-in, Left-out) With SIDRA

The analysis results for the partial intersection option are provided in Table 7.

Table 7: SIDRA results for left-in, left-out option

Traffic Type	*V/C Ratio*	*Delay (seconds)*	*LOS*
Northbound	0.02	11.9	B
Westbound	0.24	0.5	A
Eastbound	0.25	0.0	A
Total for Intersection	**0.25**	**0.4**	**A**

The SIDRA analysis of a partial intersection (Left-In, Left-Out restriction) indicates optimum operational performance and enhanced safety. All approaches achieve LOS A, with the south approach (Buckle Rd) experiencing a delay of 11.9 seconds and V/C ratio of 0.02, while the east and west approaches (Pretoria Rd) operate with delays of just 0.50 and 0 seconds and V/C ratios of 0.24 and 0.24, respectively. The overall intersection delay is only 0.4 seconds, the lowest among all evaluated designs, ensuring free-flow conditions with minimal congestion. The restriction of right-turn movements eliminates the most dangerous conflict points, significantly reducing crash risks. However, this safety improvement comes at the cost of route flexibility, as vehicles needing to turn right would have to travel further to make U-turns along Pretoria Rd, which may be inconvenient for local access and increase safety risks at these adjacent intersections.

3.7 Comparative Analysis of SIDRA and Traffic Conflicts Mitigation Tool Results

To validate the accuracy of the Traffic Conflicts Mitigation Tool's operational performance estimates, a parallel SIDRA intersection analysis has been conducted for the Pretoria Rd & Buckle Rd intersection in Silverton, Pretoria. While SIDRA Intersection modelling is widely used for capacity and delay analysis, it does not account for safety aspects such as accident probability.

This comparative analysis examines the results obtained from the Traffic Conflicts Mitigation Tool**,** which is currently under development, and those obtained from SIDRA Intersection. For validation purposes, the focus of the SIDRA-Traffic Conflicts Mitigation Tool comparison is on the following key parameters:

- Volume-to-Capacity (V/C) Ratios to assess congestion and intersection saturation.
- Delay per Vehicle (seconds) as an indicator of operational efficiency.
- Level of Service (LOS) as a performance measure for intersection control effectiveness.

Table 8: Comparison of SIDRA and traffic conflicts mitigation tool outputs

Different Intersection Operations	**Traffic Conflicts Mitigation Tool**			**SIDRA**		
	V/C	*Delay (sec)*	*LOS*	*V/C*	*Delay (sec)*	*LOS*
Existing Priority Stop-Controlled Intersection	6	90	F	3.23	40.5	E
Signalised Control (proposed alternative)	5.45	118	F	0.62	16.4	B
Traffic Circle (proposed alternative)	0.45	8.7	A	0.34	4.1	A
Partial Intersection (proposed alternative)	N/A	N/A	N/A	0.25	0.4	A

Table 8 compares the intersection performance metrics estimated by the Traffic Conflicts Mitigation Tool and SIDRA, revealing some discrepancies, particularly for the existing priority stop-controlled intersection. While SIDRA estimates a LOS of E with a delay of 40.5 seconds, Traffic Conflicts Mitigation Tool reports a more severe LOS F with a 90-second delay, likely due to differences in gap acceptance behaviour. The V/C ratios also differ significantly, with SIDRA estimating 3.23 and Traffic Conflicts Mitigation Tool reporting 6, indicating severe congestion in the latter. However, for the proposed alternatives, the results align more closely, especially for the traffic circle, where both tools

rate it as LOS A with minimal delay. The signalised control alternative shows significant differences, with SIDRA estimating 16.3 seconds (LOS B) and Traffic Conflicts Mitigation Tool reporting 118 seconds (LOS F), suggesting the need for further refinement in Traffic Conflicts Mitigation Tool's modelling of signalised intersections. Despite these variations, the comparison highlights the potential of the Traffic Conflicts Mitigation Tool as a valuable traffic analysis tool while emphasising the need for ongoing improvements to enhance its accuracy and reliability.

4. CONCLUSION

Given that the Pretoria Street classifies as a Class 2 Major Arterial and Buckle Road feeds traffic to office buildings, retail shops, restaurants, and shopping malls in the vicinity, the suggested interventions may not be suitable. Furthermore, the extrapolated 5-minute spot count results may not be accurately representative of the actual vehicle per hour rates. However, because road safety is the focus of the study, further situational assessments would need to be conducted to explore options such as changes to the road class, reconfiguration of the intersection design, etc

The TCM Tool and SIDRA analysis indicate optimal performance of a roundabout configuration, with all approaches achieving Level of Service (LOS) A and minimal delays. Roundabouts are known to facilitate continuous traffic flow, reducing delays and improving overall efficiency. They also reduce vehicle-to-vehicle conflict points when compared to traditional intersections. The likelihood of severe collisions is also significantly lowered by roundabouts and the TCM Tool confirms this through the accident probability results. The design of a roundabout inherently reduces vehicle speeds, enhancing safety for all users, including pedestrians and cyclists. The existing geometric design and land availability would hinder the implementation by making construction of a roundabout impractical at this location.

SIDRA analysis indicates excellent performance of a partial intersection (Left-In/Left-Out Restriction), with all approaches achieving LOS A and an overall intersection delay of only 0.4 seconds. This configuration ensures free-flow conditions for the major road (R104). By eliminating high-risk right-turn and U-turn movements, the design significantly reduces conflict points, enhancing safety for both vehicles and pedestrians. The partial intersection requires minimal infrastructure changes, primarily signage, pavement markings, and minor curb extensions, which makes it cost-effective and easy to implement solution. However, there is a possibility of increased U-turn movements at downstream intersections due to this solution. Although, grid layout of the area with street blocks approximately 180 meters apart, provides alternative routes, mitigating this concern. The partial intersection would also restrict direct access from the local street to the arterial road where accessibility is important for economic activity and land use integration. Considering the surrounding land use, this limitation could impact local businesses and residents.

Although the roundabout remains the most effective long-term solution, its implementation should only be considered if spatial constraints can be addressed through future redevelopment or road reconfiguration. Based on the findings, it is recommended that the partial intersection configuration be adopted as the preferred intervention. This should be complemented by targeted removal or modification of parking bays that obstruct sight distances to further enhance safety. In addition, lowering vehicle speeds at intersections is crucial, as it directly correlates with the severity of crashes. Design elements such as raised crosswalks, tight corner radii, and speed humps can effectively reduce speeds, thereby enhancing safety for all users. A self-explaining road design ensures that the intended path and behavior are clear to all users, reducing confusion and potential errors.

Applying the Safe System Approach to intersection design involves creating environments that anticipate human errors and mitigate crash impacts to prevent serious injuries and fatalities. By incorporating designs that reduce conflict points, control speeds, and enhance predictability, the overall safety of the intersection can be significantly improved. To ensure a smooth transition, it is essential to undertake a comprehensive traffic network analysis and engage with local stakeholders to address any emerging concerns, particularly those related to accessibility and circulation.

5. REFERENCES

Candappa, N, Logana, L, Van Nes, N & Corben, B. 2015. An exploration of alternative intersection designs in the context of Safe System. *Accident Analysis and Prevention*, 74:314-323.

CSIR. 2000. Guidelines for Human Settlement Planning and Design. CSIR: Pretoria.

Department of Transport. 1999. South African Road Traffic Signs Manual. Pretoria: Department of Transport.

Dunn, MR, Huang, Y & Porter, RJ. Safe System for Intersections Method Scoring: Comparing Intersection Alternatives Based on Exposure, Kinetic Energy Management, and Movement Complexity. *Transportation Research Record: Journal of the Transportation Research Board*, 2677(2). Available at: https://doi.org/10.1177/03611981221111152.

Tingvall C & Haworth N. 1999. Vision Zero – An Ethical Approach to Safety and Mobility. Proc., *6th ITE International Conference Road Safety & Traffic Enforcement: Beyond 2000*, Melbourne, Australia.Transportation.gov. (2025). What is a Safe System Approach? | US Department of Transportation. [online] Available at: https://www.transportation.gov/safe-system-approach. Accessed 11 May 2020.