THE IMPACT OF ROAD ACCESS MANAGEMENT ON TRAFFIC AND SAFETY OPERATIONS IN EMERGING URBAN CENTRES: CRITICAL ANALYSIS

OK BORE[1], OR AMBUNDA[1*] and PT JOHANNES[1]

[1]Department of Civil and Mining Engineering, University of Namibia, Namundjembo Mengela Street, Ongwediva, Namibia; *Email: rambunda@unam.na

ABSTRACT

Urbanisation poses multifaceted challenges, including traffic congestion, environmental issues, and deteriorating transportation infrastructure. The study examines the ramifications of the evolving management of road access on traffic and safety operations within Ongwediva town (Namibia), an emerging urban centre. The existence of informal access points along the roadway, influenced by varied land use developments, presents impediments to the safe conduct of traffic operations. The suboptimal performance of the transportation network is further exacerbated by outdated transportation systems, resulting in issues such as prolonged travel times and unregulated access control. Moreover, a discernible gap exists in the literature, on the interplay between access management techniques and urban traffic operations in emerging urban centres in Sub-Saharan Africa. The research gathered data on traffic characteristics and road access in Ongwediva, mapping them for a thorough analysis. The subsequent critical discussion drew upon existing empirical studies regarding the influence of access management on traffic safety and operations. The results offer valuable insights for traffic planners, emphasizing the importance of effective access management and adherence to recommended access and intersection spacing as vital components in optimizing urban traffic operations and road networks. This discussion also underscores the need for additional examination and contextualization in developing countries concerning the interplay of all facets of access management and the transport system.

Keywords: Access management, Traffic operations, Microsimulations, Urban roads, Namibia.

1. INTRODUCTION

The primary objective of transportation networks is to facilitate the efficient movement of people and goods, ensuring equal accessibility and environmental preservation (Sakamoto et al., 2010). As such, a sustainable transportation system seeks to meet essential mobility needs while safeguarding human well-being and ecological balance, fostering intergenerational fairness, affordability, efficiency, and supporting regional development (European Conference of Ministers of Transport, 2004). Urban areas in developing and emerging economies confront challenges in establishing sustainable transport systems due to rapid motorisation, resulting in congestion, and air and noise pollution. These concerns extend beyond localities, warranting national attention. These concerns require urban transport policies and guidelines to play a vital role in addressing these challenges while aligning with national objectives (Diaz & Bongardt, 2013). Access management, according to the Michigan Department of Transportation (MDOT) (2024), comprises proven techniques to alleviate traffic congestion, enhance safety, and preserve road

capacity and investment. It involves systematic control over the location, design, and operation of various elements such as interchanges, driveways and parking, thus impacting roadway design applications. Recognising the changing transportation landscape and optimising movement for active mobility users is increasingly changing the context of access management in promoting energy efficiency and encouraging efficient urban settlements (Watters et al., 2016).

Contextual investigations on access management and its impact on traffic operations and road safety in emerging cities are limited (Butorac et al., 2018), and scientific literature on transportation and traffic operations in Southern African Development Community (SADC) cities is scarce (Ntinda, 2012). This study addresses this gap by assessing existing access management and spacing in Ongwediva town (Namibia). Furthermore, the study explores the under-researched area of the impact of access management on traffic. Therefore, this study aligns with the Namibian Ministry of Works and Transport's emphasis on sustainable mobility, focusing on efficient transport systems and achieving economic, environmental, and social objectives (Ministry of Works and Transport and GIZ, 2018). The study aimed to understand the current state of access management on Mandume Ndemufayo Street in Ongwediva, identifying areas for improvement and informing on future infrastructure planning. The study examines the evolving management of road access and its ramifications on traffic and safety operations in emerging urban centres, contributing valuable insights for decision-makers to assess and adjust existing measures for improved traffic flow and safety.

Visual inspections revealed drivers using undesignated points, thus impacting transport network efficiency and safety as shown in Figure 1. The existence of informal access points along roadways, influenced by varied land use developments, presents impediments to the safe conduct of traffic operations. The suboptimal performance of the transportation network is further exacerbated by antiquated transportation systems, resulting in issues such as prolonged travel durations and unregulated access control. Additionally, a discernible gap exists in comprehending the interplay of access management techniques within multimodal scenarios. This underscores the need for the establishment of quantifiable relationships to evaluate their efficacy in conjunction with variables such as travel speed, reliability, and capacity preservation, necessitating further scholarly inquiry (Butorac et al., 2018).

Figure 1: Informal access along Mandume Ndemufayo Street (Source: Author)

In the context of Ongwediva Town in Namibia, the study gathered data on traffic patterns and access points, subsequently mapping these for comprehensive analysis. The findings underscore the significance of meticulous access management and alignment with recommended access and intersection spacing as crucial elements in augmenting road safety and optimising overall traffic operations in the dynamic milieu of urban road networks (National Institute of Transport and Road Research, 1986).

2. LITERATURE REVIEW

2.1 Road Access Management

The concept of access management emerged in the 1980s, recognising the impact of poorly located or planned access on traffic flow, safety, and aesthetics (National Research Council, 2000). The rising impact of unplanned access on highway safety, operations, and urban structure raises concern. Several researchers acknowledge the need for a systematic approach to access management, emphasising the integration of the road system into a network (Ahmed, 2013; Alsubeai, 2017; Jinghui & Xuesong, 2018). This vital strategy optimises development access, requiring a detailed examination of the interplay between land use development and transportation. Access Management is crucial not only on major highways but also on lower-order roadways such as collector streets and local streets to address safety concerns (Watters et al., 2016). It is a key component in enhancing socio-economic development, urban quality, and energy efficiency through ensuring that public transport, pedestrians, and cyclists who share road corridors with motorised transport are accommodated and have access to adjacent land use activities.

The access management guidelines offer a framework that not only fosters economic development along roads but also ensures compatibility with road standards. In areas with high traffic volumes, there exists a potential market for goods and services. Moreover, the guidelines contribute to improving the quality of the urban environment by challenging the traditional zoning approach, which tended to separate land uses without adequate consideration for environmental quality. Access management minimises carriageway crossings, enhancing the pedestrian environment, facilitating landscaping, and contributing to the overall aesthetics and traffic calming effect on arterial roads. This approach aligns with the evolving needs of urban development, promoting sustainable and multifaceted road use (Watters et al., 2016).

Some of the access management regulations typically include an access classification system, permitted access for each class, signalised and unsignalised access spacing, enforcement mechanisms, and provisions for variances. Vehicle access restriction, a novel approach to urban traffic management, involves pilot systems, such as access-restricted areas in city centres to optimise traffic flow and enhance public services (Williams & Levinson, 2008; Priya et al., 2013). Table 1 shows the prevailing access condition and the proposed design speed for urban arterials. It is, however, a challenge to meet these high design standards and speeds on urban arterials due to financial, social, political, and physical constraints. Furthermore, traffic flow conditions influence planning and the Level of Service (LOS) provided on urban streets, which are determined based on average travel speed and control delay at signalised intersections (See Table 2). The density of signals and intersection control delay significantly impacts LOS, particularly on streets with medium-to-high control densities (National Institute of Transport and Road Research, 1986; National Research Council, 2000).

Table 1: Design Speed for Arterials. Source: National Institute of Transport and Road Research, 1986

Conditions prevailing	Design speed (km/h)
1. Expressway type. No property access. At-grade intersections spacing ⩾ 500 m	80-100
2. No property access. At-grade intersections spacing ⩾ 500 m No grade separated intersections	70-90
3. Property access unavoidable but limited to low density residential land use or infrequently from commercial developments. Intersection spacing ⩾ 100 m	60-70
4. Property access unavoidable from residential or commercial land use. Intersection spacing ⩾ 100 m	50-60*
5. Central area arterial street. Close intersection spacing with traffic signal control. Pedestrian activity.	50-60*

Source: Adapted from Ref. 8, p. 14.
* The higher design speed should be used for preference.

Table 2: Urban Street Classification and LOS. Source: National Research Council, 2000

EXHIBIT 15-2. URBAN STREET LOS BY CLASS

Urban Street Class	I	II	III	IV
Range of free-flow speeds (FFS)	90 to 70 km/h	70 to 55 km/h	55 to 50 km/h	55 to 40 km/h
Typical FFS	80 km/h	65 km/h	55 km/h	45 km/h
LOS	Average Travel Speed (km/h)			
A	> 72	> 59	> 50	> 41
B	> 56–72	> 46–59	> 39–50	> 32–41
C	> 40–56	> 33–46	> 28–39	> 23–32
D	> 32–40	> 26–33	> 22–28	> 18–23
E	> 26–32	> 21–26	> 17–22	> 14–18
F	≤ 26	≤ 21	≤ 17	≤ 14

Table 3 illustrates the road classification system in South Africa and adopted in Namibia, presenting associated primary functions and equivalent type descriptions. Roads classified in the top class (1-3) prioritise access as their primary function and are identified as general major arterial roads. As the class descends (3-6), the emphasis shifts from mobility to access.

Table 3: Road Classification – Adopted from Watters et al., 2016

Class	Function	Description
Class 1	Mobility	Principal Arterial
Class 2	Mobility	Major Arterial
Class 3	Mobility/Access	Minor Arterial
Class 4	Access	Collector Street
Class 5	Access	Local Street
Class 6	Access	Pedestrian and cycle ways only*

3. METHODOLOGY

The study examined access management along a specific road section and analysed its implications on both traffic operations and safety. The methodology involved the collection of data on existing conditions, encompassing geometric attributes, roadside infrastructure, and property access along the designated street. The study focused on evaluating access control and spacing, addressing an underexplored aspect of urban mobility. Utilising a Computer-Aided Design (CAD) model with a georeferenced aerial background image, the research facilitated the identification, measurement, and assessment of spacing between intersections and access points on the street. By mapping existing access points and inter-distances, potential areas for improvement were identified, providing valuable insights for future infrastructure planning. Subsequently, a traffic condition survey of Mandume Ndemufayo Street in Ongwediva Town was conducted to gauge the existing level of access management.

3.1 Case Study Area

Mandume Ndemufayo serves as the main street through Ongwediva town, connecting feeder and access roads within the Central Business District (CBD) to residential and outskirt areas as shown in Figure 2. It also links the C46 road and the Ongwediva town, attracting significant traffic, including transit travellers.

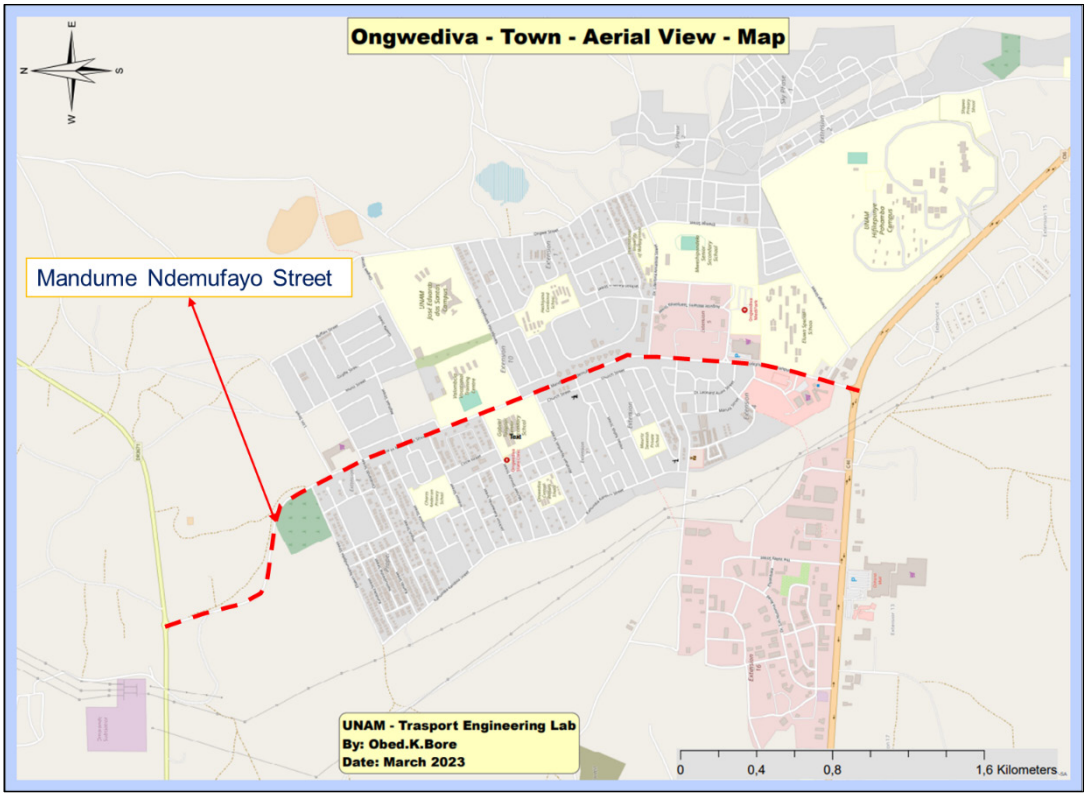

Figure 2: Location map for project area: Ongwediva Town, Namibia

3.2 Data Collection and Analysis

The study extensively utilised observational surveys for data collection, involving the systematic observation of individuals (road users) in natural environments to obtain detailed insights into natural processes (Samy, 2005; VanderStoep and Johnston, 2009). Initially, a project area background study assessed satellite maps and Geographical Information System (GIS) data. Visual inspections during site visits along Mandume Ndemufayo Street were aimed at documenting posted speeds, lane numbers, intersection configurations, and traffic conflicts. To assess access management on the project road, planned observational surveys collected relevant data, including road geometry inventory, access point locations and spacing, and informal access points. Existing design features and prevailing conditions were recorded for analysis, supplemented by GPS and GIS data such as satellite imagery. Finally, quantitative data was analysed and presented in tables and layout maps.

4. RESULTS AND DISCUSSION

4.1 Access Management Status

Traffic access points situated along main urban streets play a pivotal role in urban road networks, as they significantly impact traffic operations, making them essential

considerations in traffic analysis. The study involved observing motorist behaviour on Mandume Ndemufayo Street and the related intersections and access points, to conduct an analysis. The results, presented in Table 4 and Figure 3, reveal an average intersection spacing of 107 m, with the closest inter-junction/access points located only 17 m apart. Moreover, most access areas are situated within the CBD. In the analysis, it was determined that 67 % of intersections and access points exhibited spacing below 100 metres.

Table 4: Spacing Analysis of Junctions and Accesses along Mandume Ndemufayo Street

Segment, Road Section	Spacing (m)	If Spacing >= 100 m
00-Signal Intersection-C46 --> Access-1	71	Below
Access-1 --> Access-2	71	Below
Access-2 --> J-01	26	Below
J-01 --> Access-3	31	Below
Access-3 --> J-02	117	OK
J-02 --> Access-4	191	OK
Access-4 --> J-03	38	Below
J-03 --> J-04	98	Below
J-04 --> J-05	46	Below
J-05 --> J-06	42	Below
J-06 --> Access-5	83	Below
Access-5 --> Access-6	28	Below
Access-6 --> Access-7	25	Below
Access-7 --> J-07	82	Below
J-07 --> Informal Access1	68	Below
Informal Access1 --> J-08	82	Below
J-08 --> Informal Access2	17	Below
Informal Access2 --> J-09	389	OK
J-09 --> J-10	226	OK
J-10 --> J-11	73	Below
J-11 --> J-12	227	OK
J-12 --> J-13	234	OK
J-13 --> J-14	65	Below
J-14 --> J-15	135	OK
J-15 --> J-16	239	OK
J-16 --> Access-8	74	Below
Access-8 --> J-17	107	OK
J-17 --> J-18	123	OK
Minimum Spacing (m)	17	
Maximum Spacing (m)	389	
Average Spacing (m)	108	

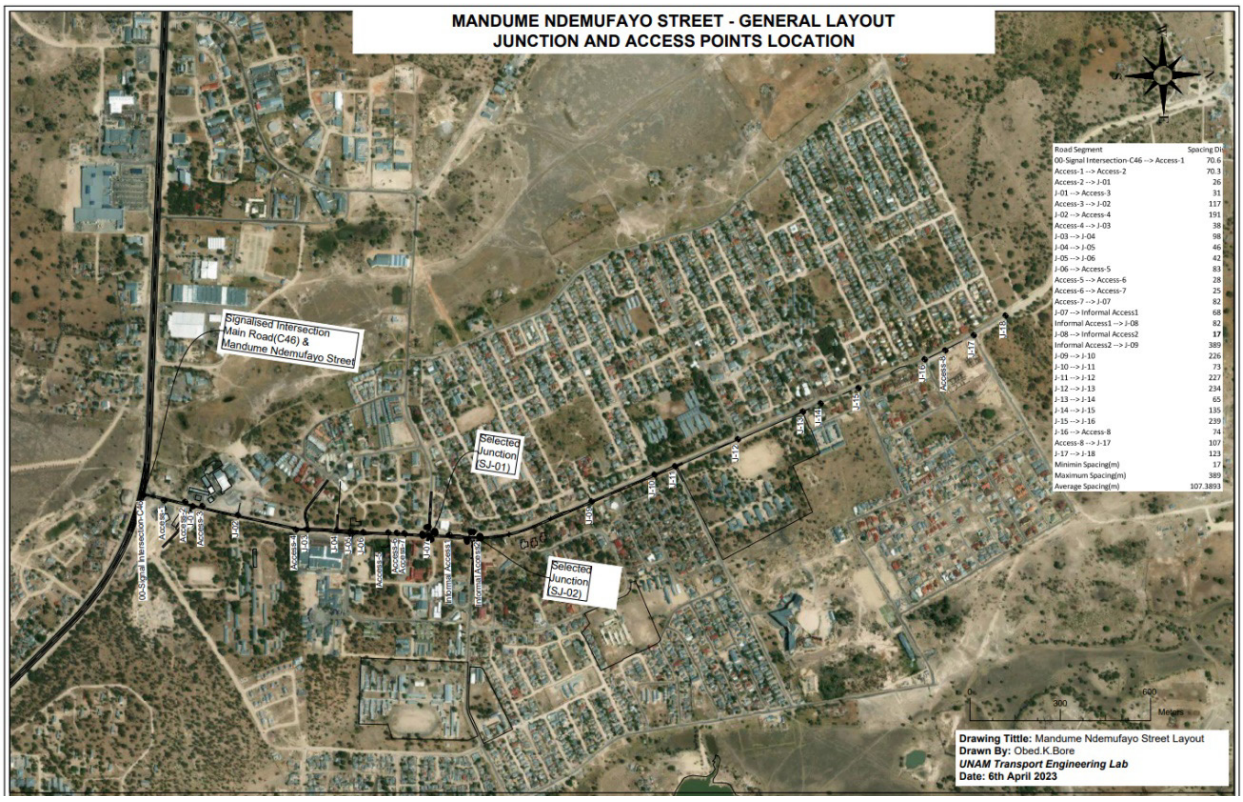

Figure 3: Junction and Access Layout along Mandume Ndemufayo Street

Focusing on T-intersections devoid of intermediate access points (driveways), 45% of such intersections along the specified stretch of Mandume Ndemufayo Street, as illustrated in Table 5, fall short of the recommended 100 m spacing (National Institute of Transport and Road Research, 1986). Moreover, approximately 85% of individual access points were found to have spacing less than the recommended 40 m (Roads Authority, 2014). Although property access is inevitable in the context of residential and commercial land use, it is recommended that the intersections should be spaced at a minimum of 100 m or more, with a maximum of six intersections per kilometre. On the other hand, while infrequent spacing accelerates traffic flow with fewer conflicts it also leads to higher traffic and turning volumes at the limited intersections (National Institute of Transport and Road Research, 1986). Therefore, access management directly influences the efficiency of urban arterial streets, whether designed formally or informally (Zhou et al., 2008), and impacts the safety of all road users, especially active mobility users.

Table 5: T-Intersection Spacing on Mandume Ndemufayo Street

Section Between Intersection	Spacing (m)	Criteria (>= 100 m)
J-03 --> J-04	98	Below
J-04 --> J-05	46	Below
J-05 --> J-06	42	Below
J-09 --> J-10	226	OK
J-10 --> J-11	73	Below
J-11 --> J-12	227	OK
J-12 --> J-13	234	OK
J-13 --> J-14	65	Below
J-14 --> J-15	135	OK
J-15 --> J-16	239	OK
J-17 --> J-18	123	OK

Visual inspection of the street revealed that some of the existing access points along Mandume Ndemufayo Street exhibited signs of deterioration, possibly due to inadequate maintenance and continuous erosion. This deterioration could lead to vehicle breakdowns for vehicles using these areas to enter or exit the main street, particularly since certain sections of the road are at higher grades than the existing ground. Additionally, during the survey of the street, the study observed a tendency among motorists to enter and exit the main road at undesignated points. The sections of informal access points were identified. Most of these areas could be found near shopping centres and at the intersections as shown in Figure 4 and Figure 5. Figure 5 shows a truck exiting Mandume Ndemufayo Street at point B (corresponding to the location shown in Figure 4 Point B). Such undesignated entry and exit manoeuvres could also raise safety concerns due to the interruption of through traffic movements. Moreover, the satellite image analysis indicated no intention or planned entry or exit at the identified informal access points along the project road. The presence of displaced or missing road edge kerbs at similar locations, observed during site visits, could further support the idea of informal non-intended access points.

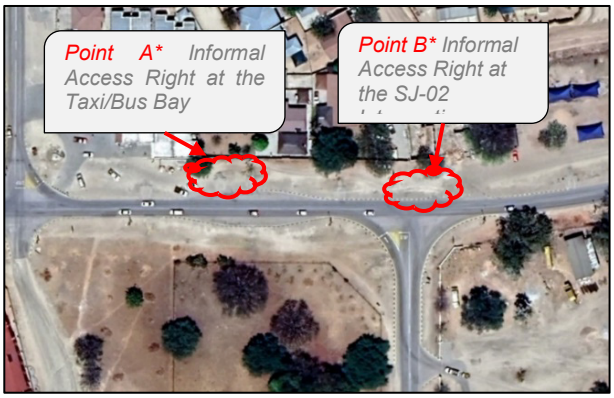

Figure 4: Sections of Informal Access to MND Street (Source: Google Earth)

Figure 5: Informal access at Intersection:(Town Council)

4.2 Critical Discussion and Implications

The preceding examination and assessment of the current access management, which considers the condition and spacing of unsignalised access points along Mandume Ndemufayo Street, may serve as a foundation for understanding multimodal access management and its potential implications for town traffic operations. However, it is important to note that simulating the effects of the existing access management was not within the project's scope. Nonetheless, a literature review has been conducted to provide a reference regarding the potential influence of access management on traffic operations.

Butorac et al.'s (2018) guide extensively examined more than 70 access management methods and their impact on the safety and efficiency of a wide range of road users, such as motorised vehicles, pedestrians, bicyclists, buses, and trucks. Previous research has demonstrated that efficient access management can reduce conflict points on roads, leading to decreased traffic congestion and road crashes (Karlaftis & Golias, 2009; Ambunda & Sinclair, 2022). However, there is a notable gap in understanding how access management techniques interact in multimodal scenarios, necessitating the development of quantifiable relationships to assess their effectiveness in conjunction with factors like travel speed, reliability, and capacity preservation. This underscores the need for additional research. The text underscores the importance of achieving a balance between accessibility and mobility in road and land use planning, particularly in diverse

transportation settings. The transportation system should accommodate various types of users, and several factors, including turning patterns, access density, and infrastructure design, can influence corridor operations. The guide is designed to complement the expertise of design professionals across different contexts. As one of the access management strategies, the reduction of unsignalised access points is acknowledged as an effective approach. The technique aims at diminishing the number of access points along a roadway, augmenting the spacing between unsignalised access points, or implementing a combination of both measures. Minimum distances are put into practice along a roadway between consecutive unsignalised connections, and the distance between roadway intersections and the nearest access point is established. Furthermore, the positioning of access points on opposing sides of the roadway can also be prescribed (Butorac et al., 2018).

4.2.1 Safety Implications

Access spacing significantly influences crash rates, with an exponential increase in crash rates corresponding to a higher number of accesses per kilometre (Mitra et al., 2017). Reducing access points leads to a proportional decrease in conflict points, positively impacting road safety. Given that up to 50 % of all road crashes occur at intersections, minimising access points potentially contributes to enhanced safety (Mongiardini *et al.*, 2021). Figure 6 illustrates crash rates concerning median type and total access frequency for both urban and suburban conditions. The addition of each driveway results in an incremental annual crash rate increase ranging from 0.07 to 0.11 (Watters et al., 2016).

Access density, defined as the number of unsignalised intersections per kilometre, correlates with an escalation in relative collision rates. Considering that the acceptable spacing may be influenced by surrounding land uses, the spacing of unsignalised intersections should be evaluated case by case. In instances where unsignalised intersections are anticipated to be signalised in the future, adherence to signal access spacing is recommended (CIMA+, 2023).

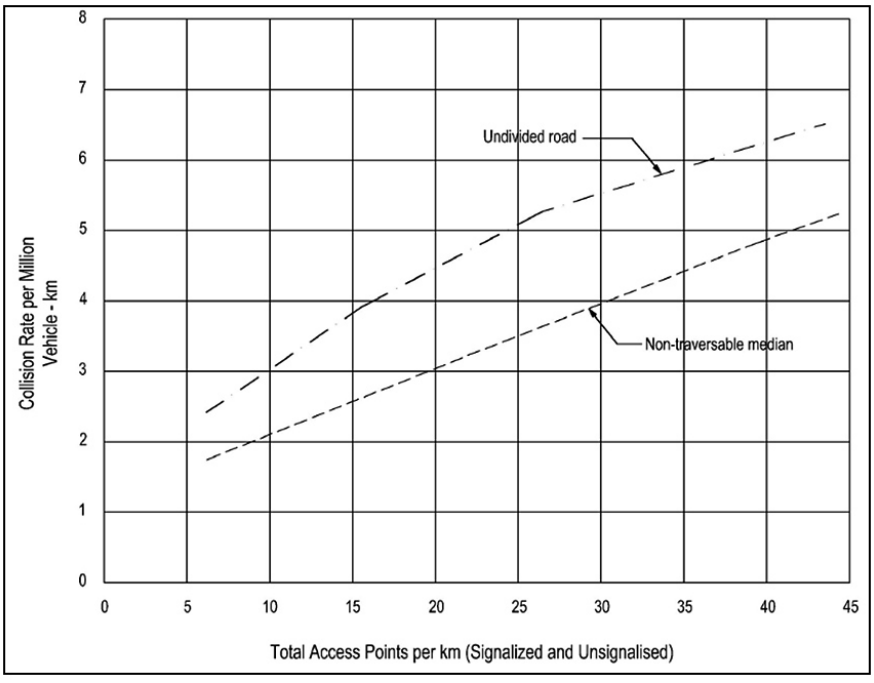

Figure 6: Crash rate increase with the number of access points
Source: (Watters et al., 2016)

4.2.2 Operational Implication

Research findings demonstrate notable improvements in traffic operations and safety through the application of the reduction of access points technique (Mitra et al., 2017). For instance, the unimpeded flow of motor vehicles and travel speeds can increase by several kilometres per hour. The improvements are more pronounced when the number of through lanes is reduced, when through traffic volumes are higher, and when turning traffic volumes are higher (Texas Transportation Institute et al., 2008; Transportation Research Board, 2016). Greater distances between access points allow for the provision of turn lanes (Williams et al., 2014; Dixon et al., 2016). It is important to note that these findings are primarily based on studies conducted in the USA and Western contexts, and thus the need for more contextualised studies in Sub-Saharan Africa. It is also notable that Access management has an advantageous impact on enhancing road operations by minimising delays attributed to access points. The presence of frequent access points and closely spaced traffic signals contributes to congestion on major roadways. Research indicates that inadequate spacing and positioning of driveways can lead to a notable reduction in average travel speeds on the main road, with potential decreases of up to 15 km/h reported (Watters et al., 2016).

4.3 Access Spacing Strategies

Effectively managing access points on a regional road network is crucial to minimise delays, turn conflicts, and maintain safety for all road users (CIMA+, 2023). Before allowing direct access to main arterial road roads, alternative access options must be explored and the necessity for such access demonstrated. Intersections, both signalised and unsignalised, are major points of traffic conflicts. Therefore, preserving the functional area of intersections and interchanges is critical to avoid traffic conflicts and enhance safety. Provision of clear functional areas, both upstream and downstream, is essential for safe operation (Watters et al., 2016). Typically, guidelines specify optimal intersection spacing, acknowledging potential deviations and the need for engineering judgment. Strict adherence to standards may limit adaptable decision-making, hindering the exploration of practical or innovative solutions in specific contexts (Watters et al., 2016; Butorac et al., 2018).

Implementing effective access management involves a set strategy. These include integrating access management principles into local comprehensive plans, restricting the number of driveways per lot to generally one per parcel, positioning driveways away from intersections, and consolidating driveways to enable seamless travel between parcels without re-entering arterial roads. Additional strategies include emphasising residential access through neighbourhood streets, increasing minimum lot frontage on major streets, advocating for a connected street system, and promoting internal access to out parcels in shopping centres on arterial streets. Regulating the location, spacing, and design of driveways should be done in close coordination with the planning authorities. These are essential measures to ensure effective access management (CUTR, 1998; Victoria Transport Policy Institute, 2014).

Enhancing access management involves addressing several issues that contribute to suboptimal conditions. To improve the situation, it is crucial to inform all road agencies about local rezoning or changes in land use along trunk lines. Additionally, local site plan review and approval processes should involve all relevant road agencies, and driveway permit applications should be scrutinised by road agencies before site plan approval. Ensuring that roadway reconstruction and resurfacing projects adequately consider access issues is imperative. Offering access management education to local government officials

can increase awareness of traffic impacts resulting from local land use decisions. Collaboration between state and local governments in the form of dedicated teams is a key strategy to effectively manage the granting and control of access to trunk lines, contributing to the resolution of these issues (The Michigan Department of Transportation (MDOT), 2024).

5. CONCLUSIONS AND RECOMMENDATION

This study assessed access management concerning access spacing along Mandume Ndemufayo Street in Ongwediva Town. The findings revealed an average intersection spacing of 107 m, with the closest inter-junction/access points only 17 m apart, predominantly concentrated within the Central Business District (CBD). Notably, 67% of intersections and access points exhibited spacing below 100 metres, with the presence of informal access points along the street. While intersection design influences road network safety and level of service, effective access point management is crucial. The study suggests adhering to recommended guidelines (especially at urban planning and design stages), suggesting a minimum spacing of 100 metres or more between intersections, with a maximum of six intersections per kilometre. This approach promotes efficient traffic flow, minimises conflicts, and facilitates higher traffic and turning volumes at limited intersections (National Institute of Transport and Road Research, 1986). The literature supports the pivotal role of access point management in enhancing traffic flow and road safety. Although not simulated, research indicates traffic operation and safety improvements through reduced access points (Williams et al., 2014; Dixon et al., 2016). Adherence to recommended intersection spacing guidelines can enhance efficiency by minimising conflicts, and acknowledging variations in traffic and turning volumes. However, strict adherence may challenge service provisions to surrounding developments (National Institute of Transport and Road Research, 1986). Proper access management and alignment with recommended spacing positively contribute to road safety and overall traffic operations in dynamic urban road networks. The study focuses on access control's impact on traffic, particularly access spacing, highlighting the need for further research, especially in developing nations and within the broader context of mobility planning. Integrating GIS technology with Global Positioning Systems could enable optimal automated real-time warning systems. Overall, ITS research, incorporating novel Artificial Intelligence (AI) and Machine Learning (ML) frameworks like machine vision and remote sensing, holds potential for sun glare mitigation and real-time data collection and process automation in this context.

6. LIMITATION

The study focused on Mandume Ndemufayo Street in Ongwediva, selecting intersections with extended queue lengths for analysis based on visual inspections during site visits. The study exclusively delved into the intersection and access spacing technique of access management, highlighting the need for more research on collective interventions in access management and their broader impact on traffic safety, operations, and the transport system. To provide a more comprehensive understanding, further exploration of multifaceted access management is warranted.

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