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A Transportation System Performance and Safety Analysis of Juba, South Sudan

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Research Article

Keywords: Transportation systems, traffic safety, infrastructure capacity, South Sudan, urban mobility, post-conflict development

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The data collected for this research can be found at the following data repository: Lyons, William (2026), “Juba Traffic Data”, Mendeley Data, V2, doi: 10.17632/hbn7t8cg6r.2.

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Abstract

This study presents a comprehensive analysis of the transportation system in Juba, South Sudan, examining traffic flows, infrastructure capacity, and road safety at critical urban intersections. This research reveals significant challenges in urban mobility and safety through systematic data collection and analysis of traffic patterns at major intersections including Gudele Road at Rock City Road, University of Juba Roundabout, Custom Roundabout, and Seventh Day Roundabout. The study finds severe capacity constraints with volume-to-capacity ratios exceeding 1.6 during peak hours at major intersections, while safety analysis indicates concerning crash patterns with motorbikes involved in 54.6% of all traffic movements yet representing the highest risk category. Annual crash data shows 113 recorded incidents with a 77.8% injury rate, concentrated among drivers aged 26-35 years. The research contextualizes these findings within the broader East African transport landscape and South Sudan's post-conflict infrastructure development trajectory. Key recommendations include immediate traffic signal implementation, dedicated motorcycle infrastructure, enhanced enforcement mechanisms, and comprehensive road safety education programs targeting high-risk demographics.

Keywords: Transportation systems, traffic safety, infrastructure capacity, South Sudan, urban mobility, post-conflict development

1. Introduction

South Sudan, the world's youngest nation, faces unprecedented challenges in developing sustainable urban transport systems. As a post-conflict state that gained independence in 2011, the country's infrastructure development has been severely constrained by decades of civil war, limited resources, and ongoing security challenges. The capital city of Juba represents the primary urban center and serves as a critical case study for understanding transport dynamics in rapidly urbanizing post-conflict environments.

The importance of transportation infrastructure in post-conflict recovery cannot be overstated. As noted by development economists, transport systems form the backbone of economic recovery, social integration, and humanitarian access. In South Sudan's context, where only 2% of the existing road network is paved, and most roads are impassable during the wet season (African Development Bank, 2013; Worlddata.info, 2024), understanding current traffic patterns and safety challenges becomes essential for informed policy development and infrastructure investment.

This research addresses a critical knowledge gap by providing the first comprehensive analysis of traffic flows and safety patterns at key intersections in Juba. Through systematic data collection and analysis, we examine the performance of critical urban intersections, assess infrastructure capacity constraints, and analyze road safety patterns that affect thousands of daily commuters and economic activities.

2. Literature Review

2.1 East African Transport Context

Understanding the transportation challenges facing South Sudan requires examining the broader East African context. Scholars have noted that urban centers across the region tend to experience similar pressures, including swift population growth in cities, rising vehicle ownership, and substantial gaps in transport infrastructure (Pojani & Stead, 2015). Pirie's work on mobility in anglophone Sub-Saharan Africa further highlights how cities in this part of the continent struggle with underdeveloped public transit networks, deteriorating roads, and disproportionately high pedestrian death tolls (Pirie, 2004).

South Sudan's roads rank among the most hazardous in the world. Between 2015 and 2019, the country recorded roughly 3,693 traffic-related deaths annually, translating to approximately 34.8 deaths for every 100,000 people - more than double the worldwide rate of 16.8 per 100,000 (World Health Organization, 2023). This grim statistic reflects a continent-wide pattern: Africa's estimated road fatality rate of 26.6 per 100,000 exceeds that of every other region, surpassing Southeast Asia's 17.0, the global mean of 17.5, and Europe's 9.3 per 100,000 (World Health Organization, 2023).

Throughout East Africa, motorcycle taxis - widely known as "boda-bodas" - have become a dominant mode of transport, with profound consequences for both urban mobility and traffic

safety (Kisaalita & Sentongo-Kibalama, 2007; Howe & Maunder, 2004). In Kampala, official records from the city authority indicated approximately 120,000 motorcycles on the register, though a spokesperson for the local riders' association suggested actual numbers were likely higher due to unregistered vehicles (Kamuhanda & Schmidt, 2009). The safety implications are stark: motorcycle-related fatalities in Uganda more than doubled over a seven-year span, climbing from 621 in 2014 to 1,404 by 2021 (Voice of America, 2024).

The rise of motorcycle taxis in the region is rooted in particular economic and geographic circumstances. The name itself traces back to cross-border smuggling operations between Uganda and Kenya during the 1980s and early 1990s, when individuals transported goods on foot, by bicycle, or by motorcycle. Because the service shuttled goods between national borders, it became colloquially known as "boda-boda" - a phonetic rendering of "border to border" (Howe & Maunder, 2004; Perschon, 2004). More broadly, the growth of boda-boda services across East Africa reflects grassroots entrepreneurship spurred by greater access to bicycles and motorcycles (Kisaalita & Sentongo-Kibalama, 2007). The sector has thrived in large part because formal public transit systems have failed to meet demand in economies where most people depend on shared transport.

Sustainable transport projects elsewhere in the region may offer instructive examples for South Sudan. Dar es Salaam pioneered bus rapid transit in East Africa and remains the sole African city to have received the Sustainable Transport Award. Its DART system covers a corridor of 20.9 kilometers and serves around 172,000 riders daily, providing quicker travel times aboard high-capacity vehicles (ITDP, 2017).

2.2 South Sudan's Infrastructure Trajectory

South Sudan's transport infrastructure development must be understood within its historical context of prolonged conflict. According to the African Development Bank, decades of civil war basically inhibited the provision of basic infrastructure, and this undermined much of its production capacity (African Development Bank, 2013). By April 2018, it was estimated that about 400,000 people, 10.6% of which were children, had been killed in the war (International Organization for Migration, 2024). The infrastructure legacy of conflict is profound, with some of the facilities that were put in place several decades ago damaged by the civil war and there have been negligible amounts of routine maintenance (African Development Bank, 2013).

Current infrastructure deficits are extreme even by regional standards. According to the African Development Bank, less than 300 kilometers of paved roads exist in the entire country, most of them in and around Juba (African Development Bank, 2013). This accounts for only 2% of the existing road network in South Sudan being paved, and most roads are impassable during the wet season making it difficult if not impossible for rural people, which raises the transportation costs and also hinders the movement of goods from rural areas to urban centers and markets in the country (SFASID, 2020; Worlddata.info, 2024). The road network covers 90,200 km total length, representing 7.85 meters for each of the country's 11.48 million inhabitants. This puts South Sudan in place 56 in the global ranking for road density, with only 0.3 percent, i.e. 300 km, of roads asphalted roads (Worlddata.info, 2024).

Recent development initiatives show promise but face implementation challenges. Ethiopia has extended a $738 million loan to South Sudan to fund the construction of a road connecting the two countries (Ethiopian News Agency, 2024). The South Sudan Transport Sector Development Project is intended to improve transport in the country with World Bank backing (Global Highways, 2024). A number of road connections will be placed as a priority for maintenance and improvement works. These include the 193km route between capital Juba and Nimule, the 350km route linking Malakal with Nasir and Jikao and the 360km route connecting Wau with Raja, Boro and Medina (Global Highways, 2024).

2.3 Regional Road Safety Patterns

he scale of road safety challenges across East Africa is considerable, set against the backdrop of Africa recording the highest estimated road traffic death rates in the world. Pedestrians account for 38% of all road fatalities on the continent, while those traveling inside vehicles represent 43% (World Health Organization, 2023). Within this broader crisis, East Africa faces an especially acute burden of traffic-related injuries among those least protected on the roads (Khayesi et al., 2010). Uganda illustrates this pattern clearly: in 2016, nearly half of all collisions and roughly one in five deaths from crashes were concentrated in Kampala alone (Kamuhanda & Schmidt, 2009). Meanwhile, research from Kenya has identified human behavior as the dominant cause of collisions at 59.6%, followed by vehicle defects at 29.9% and poor road conditions at 19.5% (Aligula et al., 2003).

Findings from Juba paint a similarly troubling picture. According to research published in the South Sudan Medical Journal, men were behind the wheel in the overwhelming majority of recorded collisions - 99% - compared to just 1% involving female drivers. Motorcyclists represented the second-largest vehicle category involved in crashes after private cars, accounting for roughly a quarter of all incidents. Notably, alcohol played almost no role, with 99.5% of drivers testing sober at the time of their accidents, pointing toward deficiencies in road design and traffic regulation as the primary contributors to collisions rather than driver impairment (South Sudan Medical Journal, 2017).

Residents of Juba have grown increasingly alarmed by the frequency of traffic accidents. Many drivers lack familiarity with posted signage, and there is a persistent absence of structured road safety education. Seasonal patterns also emerge in the data, with August recording the highest share of incidents at 11%, a period marked by heavier rainfall that degrades driving conditions (South Sudan Medical Journal, 2017).

Motorcycle use across the region raises distinct safety concerns. Studies conducted in several East African urban centers have found that only around one in five riders use protective helmets (Mahlstein, 2009). Boda-boda operators have gained a reputation for reckless riding practices—weaving through narrow gaps, ignoring signals and traffic rules at junctions, carrying excessive numbers of passengers or oversized loads, and frequently riding without helmets or straying from designated lanes (Agbiboa, 2019).

2.4 Local Observations

During the author's residency in Juba from 2020 to 2024, the author documented anecdotal observations of traffic operations and considerations for traffic safety. The observations to be included here are the scale of traffic congestion, the existence of informal contra lanes, and the sheer scale of animals intermingled with vehicles and trucks. These observations are recorded below.

The scale of traffic congestion in Juba, particularly on the Gudele Road (but also on all major arterials and collectors), was unimaginable. The morning and evening commutes, from Acacia Village to the US Embassy in Thongpiny, was only 6.6 kilometers, but this commute often takes an average travel time of one hour with predictable congestion, aggressive driving, and severe traffic accidents.

The most obvious consequence of this congestions was the spontaneous implementation of a contra flow lane on the Gudele Road. The Gudele Road is a median divided four lane road with two lanes in each direction. When traffic congestion reached the point of gridlock, traffic would divert from the correct side of the median to the opposite side of the median. Sometimes this was aided by local traffic police. Sometimes it occurred organically. A photograph of the spontaneous contra flow lane diversion is shown in Figure 1.

Insert Figure 1.

When this occurred, traffic would divert at a break in the median and travel in the opposing direction lane adjacent to the median. The opposing direction would relegate itself to one lane, allowing traffic to flow in a spontaneous contraflow lane in the other lane. In this manner, traffic capacity was potentially increased by 50% by adding a third lane in the peak direction of traffic.

In the morning peak period, on Gudele Road eastbound, contemporaneous observations of traffic operations on March 23, 2021, revealed that 2,767 vehicles diverted to the westbound side of the median, in an informal contraflow lane, with a peak 15 minute volume of 380 vehicles. In the evening peak period on the same date, on Gudele Road westbound, observations revealed that 3,282 vehicles diverted to the eastbound side of the median in an informal contraflow lane, with



Figure 1 - Contraflow Lane in Operation

a peak 15 minute volume of 520 vehicles. The capacity and safety implications of this informal arrangement are obvious and significant. Figure 2 depicts the contra flow lane in operation.



Figure 2 - Contraflow Lane in Operation

Insert Figure 2.

While the author has traveled extensively in developing economies, the omnipresence of animals in traffic was very notable, especially given the intensity of traffic congestion. South Sudan is a pastoral society. As such, it is expected that animals would be present throughout the community. However, it was very surprising to see herds of cattle driven down the Gudele Road during peak periods. The existence of livestock in peak periods also included significant numbers



of goats and lambs, either being driven or simply wandering in traffic, with predictable effects. A photograph illustrating the mix of traffic, with livestock, boda-bodas, tuktuks, and motor vehicles is depicted in Figure 3.

Insert Figure 3.

Figure 3 - Traffic Mix in Juba (Cattle, Boda-Bodas, Tuktuks, Autos, Minibuses, and Pedestrians)

Finally, it is important to note that, while vehicular traffic is the dominant form of transport in Juba, there are still significant amounts of donkeys pulling wagons. These donkeys are pulling their load in mixed traffic, with tuktuks, boda-bodas, trucks, and all manner of other vehicles. While the safety of the animals must be of some concern, the safety of other road users was equally concerning given the occasionally unpredictable behavior of the donkeys.

The resulting image of traffic in Juba is a cacophony of sights, sounds, and discordant modes of transportation. The economic lifeblood of the city is disorienting to any newcomer. Despite the chaos, the system works for most residents, although there is substantial room for improvement. Photographs of a wide variety of city streets are depicted in Figure 4.

Insert Figure 4.



Figure 4 - Various Local Streets in Juba

2.5 Roadway Inventory

The local observations and data collection were primarily focused on the intersection of the Gudele Road and Rock City Road. The Gudele Road is a paved, median divided, four lane arterial. It runs east-west, connecting the payams[1] of Gudele, Yambio, and Munuki to downtown Juba. Rock City Road (also known as the Juba Bypass) runs north-south and is an unpaved two lane road, which widens at the intersection to provide at least two lanes on each approach (oftentimes more informal lanes develop). This intersection operates with the Rock City Road approaches under stop control (no stop signs exist, however) with the Gudele Road having the right-of-way.

During peak periods, this intersection operates with traffic police periodically stopping east-west traffic to allow vehicles from Rock City Road to take a left onto the Gudele Road. While this operation is chaotic and very informal, previous attempts to install traffic signals failed. A donor

[1] A payam is a geographical jurisdiction, roughly equivalent to a township or a village.

funded development project once installed solar powered traffic signals at this location, but nearly all of the infrastructure was pilfered for scrap by thieves. A photograph of a defunct traffic signal is depicted in Figure 5.

Insert Figure 5.



Figure 5 - Abandoned and No Longer Functioning Traffic Signal. Note Missing Solar Panel

3. Methodology

This study employed a mixed-methods approach combining quantitative traffic analysis with comprehensive safety assessment across multiple data sources and time periods. Data collection was conducted through systematic observation and record analysis at key intersections in Juba. This chapter gives a summary of the methods applied, with further details provided in the following chapter.

The data collected for this research can be found at the following data repository: Lyons, William (2026), “Juba Traffic Data”, Mendeley Data, V2, doi: 10.17632/hbn7t8cg6r.2.

3.1 Traffic Volume Analysis

Traffic volume data was collected at the Gudele Road and Rock City Road intersection through systematic counting over multiple time periods. The traffic mix comprised of five distinct motorized modes including motorbikes, automobiles, minibuses, trucks and tuk-tuks, and three non-motorized modes including bicycles, pedestrians, and animal-drawn carts. Data collection focused on both morning (07:00-09:00) and evening (16:00-18:00) peak periods to capture maximum traffic flows.

3.2 Capacity Analysis

Highway Capacity Manual (HCM) methodology was applied to assess intersection performance. Volume-to-capacity ratios were calculated using assumed lane capacities of 1,800 vehicles per hour per lane for major streets and 1,500 vehicles per hour per lane for minor streets. Level of Service (LOS) assessments were conducted to determine operational efficiency.

3.3 Safety Analysis

Comprehensive crash data was collected from multiple sources including:

- State Directorate of Traffic Police records
- Hospital emergency department records
- Field observation data from specific intersections
- Multi-year trend analysis covering 2017-2021 periods

Safety analysis included crash type classification, demographic analysis of involved parties, temporal patterns, and severity assessments across different intersection configurations.

3.4 Comparative Intersection Analysis

Detailed comparative analysis was conducted across three major intersections: University of Juba Roundabout, Custom House Roundabout, and Seventh Day Roundabout. This analysis examined crash frequencies, vehicle involvement patterns, and temporal distributions to identify high-risk locations and contributing factors.

4. Results and Analysis

4.1 Comprehensive Traffic Volume Patterns and Modal Distribution

The traffic analysis at Gudele Road and Rock City Road intersection encompasses both detailed daily operational assessment (August 6, 2021) and comprehensive traffic classification analysis based on the extensive five-day traffic counts that were conducted in March 2021. This multi-dimensional approach provides critical insights into both peak-hour capacity constraints and broader transportation system characteristics.

Comprehensive Traffic Classification Analysis (5-Day Counts)

The extensive five-day traffic counts revealed the multimodal nature of traffic at this critical urban intersection, with 78,115 total movements recorded across eight distinct vehicle classes (Fig.6), including motorbikes, automobiles, minibuses, trucks, pedestrians, tuk-tuks, bicycles and animal carts. This comprehensive data set provides essential insights into the transportation ecosystem that characterizes Juba's urban mobility patterns.

Insert Figure 6.

TRANSPORTATION MODE	EASTBOUND VOLUME	WESTBOUND VOLUME	TOTAL VOLUME	MODAL SHARE (%)
Motorbikes	22,799	19,882	42,681	54.64%
Automobiles	10,729	6,173	16,902	21.64%
Minibuses	6,273	6,320	12,593	16.12%
Trucks	1,438	584	2,022	2.59%
Pedestrians	807	1,421	2,228	2.85%
Tuk-tuks	969	502	1,471	1.88%
Bicycles	105	113	218	0.28%
Animal Carts	0	0	0	0.00%

Figure 6 - Traffic Counts

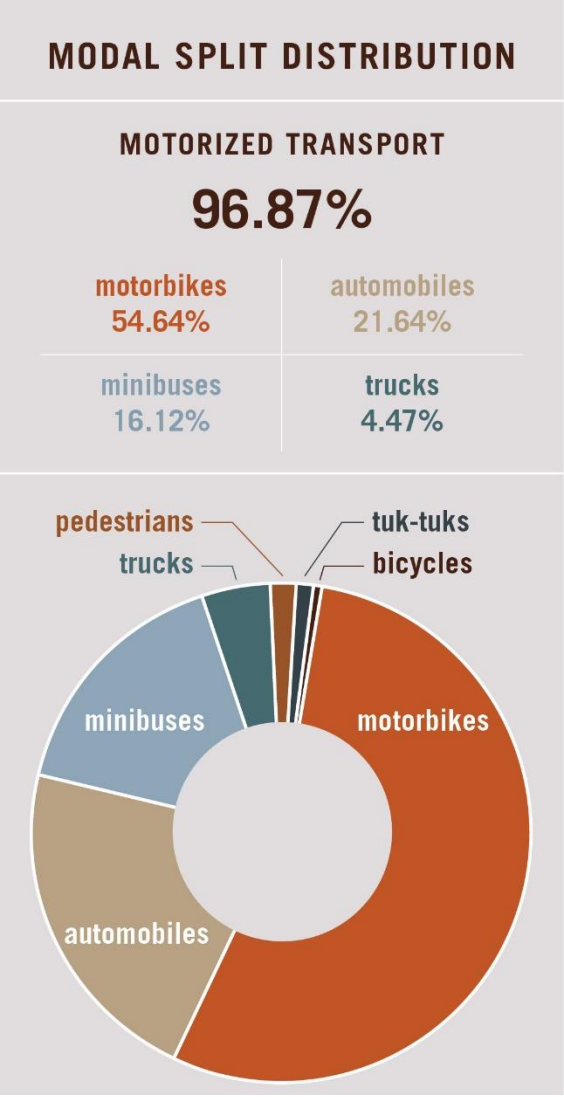


Figure 7 - Modal Split Distribution

Overall Modal Split Distribution

The modal split analysis of Juba's transportation ecosystem reveals a landscape overwhelmingly dominated by motorized vehicles (96.87%), with a clear hierarchy in usage patterns (Fig 6 & 7). Motorbikes lead by a wide margin, accounting for 42,681 counts or 54.64% of the traffic mix, establishing themselves as the primary mode of transport. Automobiles follow with 16,902 counts (21.64%), indicating a substantial presence of private vehicles. Public transport demand is reflected in the 12,593 movements by minibuses, representing 16.12% of the total.

Insert Figure 7.

Pedestrian activity is notably low, with only 2,228 movements (2.85%), raising concerns about walkability and pedestrian infrastructure as auto ownership is particularly low as expected in a typical African country, necessitating high volumes of pedestrian activities, if it were safe. Trucks contribute 2,022 movements (2.59%), suggesting limited heavy commercial activity. Tuk-tuks, with 1,471 movements (1.88%), are emerging as an intermediate transport mode, while bicycles, at just 218 movements (0.28%), show minimal use of non-motorized transport. Traditional modes such as animal carts were not observed during the data collection period[2].

Critical Transportation Pattern Insights:

Motorized Vehicle Dominance: The analysis demonstrates that 96.87% of all traffic consists of motorized vehicles, with non-motorized transport representing only 3.13% of the traffic mix. This motorization level indicates a transportation system that has evolved toward mechanized mobility solutions, typical of rapidly developing urban areas where traditional transport modes have been displaced.

Motorcycle Transportation Backbone: The predominance of motorbikes at 54.64% represents more than half of all recorded vehicles, suggesting that motorcycles serve as the primary means of transport for the majority of travelers. This two-wheel preference reflects transportation patterns typical of developing urban areas where motorcycles offer affordable, maneuverable solutions to urban mobility challenges and congestion avoidance.

Public Transport Significance: Minibuses account for 16.12% of the traffic, indicating substantial demand for transport services. The significant minibus presence suggests the importance of public transport in serving this corridor and highlights potential for enhanced public transport development. Unfortunately, the current minibus network is entirely controlled by the informal sector as in many African countries, with no central coordination or oversight, other than a taxi licensing scheme.

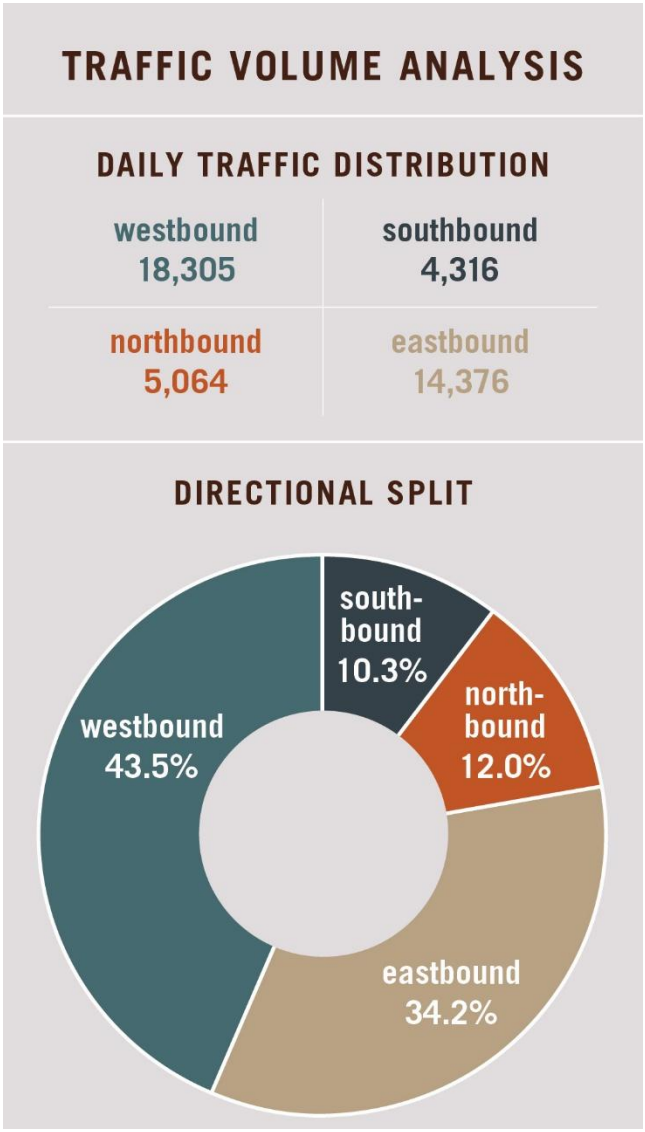
Non-Motorized Transport Deficiency: The virtual absence of non-motorized transport modes - pedestrians at 2.85% and bicycles at 0.28% - indicates either inadequate infrastructure for walking and cycling, safety concerns that discourage these modes, or cultural preferences that favor motorized transport. The complete absence of animal-drawn carts suggests full modernization away from traditional transport modes.

Directional Flow Analysis and Modal Patterns

Asymmetric Traffic Distribution:

[2] While cattle and donkeys were not observed at the time of data collection, they are frequently found in mixed traffic.

A directional analysis of traffic flow in Juba reveals a significant imbalance that carries important implications for infrastructure planning and traffic management. The major corridor is a three-lane road with a mountable median. The eastbound traffic had 43,120 vehicles, representing 55.2% of the traffic mix, while westbound traffic trails behind with 34,995 vehicles, or 44.8% (Fig 8). This 21.6% higher volume in the eastbound direction during the morning peak suggests underlying land use patterns, likely driven by employment centers or major destinations that generate increased travel demand heading east. The pattern reverses during the evening peak with the heavier traffic headed westbound.



In response to these imbalances and the resulting directional congestion, local residents have informally implemented a contraflow lane on Gudele Road. While this adaptation reflects the community's resilience and resourcefulness, it is far from a comprehensive solution and highlights the urgent need for formal traffic engineering interventions.

Figure 8 - Directional Distribution

Insert Figure 8.

Modal Distribution by Direction:

A detailed analysis of modal travel patterns reveals distinct behavioral characteristics among road users in Juba (Fig. 9). Eastbound traffic shows a higher concentration of private vehicles, with 10,729 automobiles recorded, alongside a substantial flow of motorbikes totaling 22,799. Public transport in this direction appears balanced, with 6,273 minibuses, while commercial

activity is relatively high, indicated by 1,438 trucks. Pedestrian movement, however, is comparatively low, with only 807 recorded crossings.

Insert Figure 9.

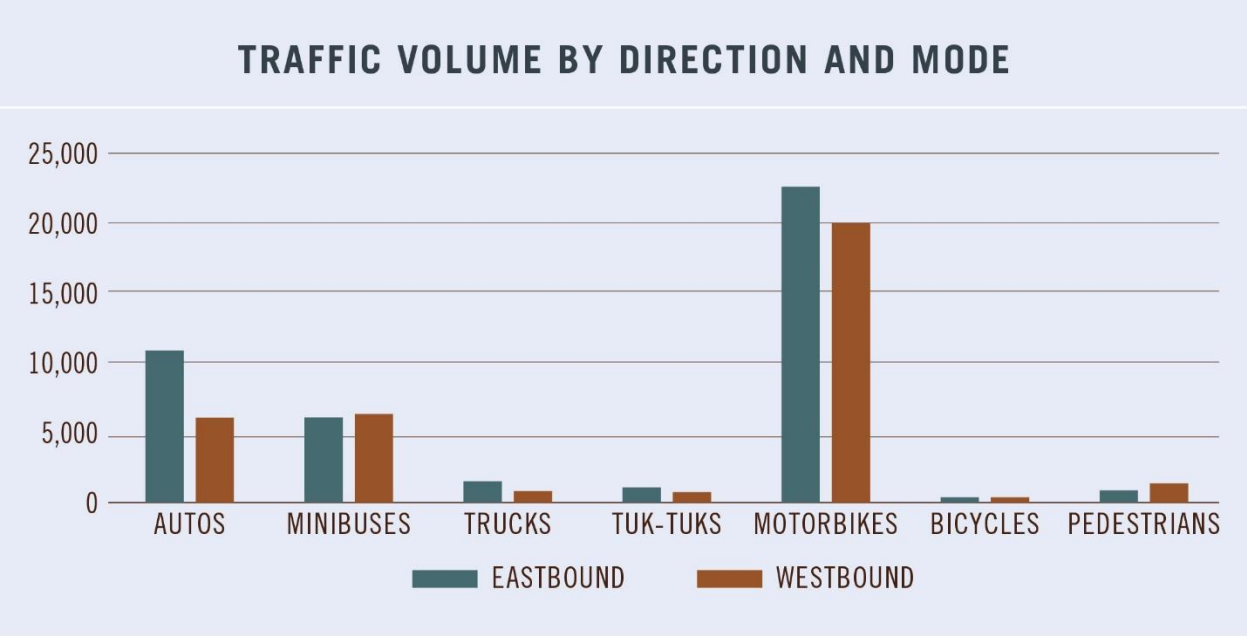


Figure 9: Traffic Volume by Direction and Mode

In contrast, westbound traffic reflects reduced private vehicle demand, with just 6,173 automobiles. Motorbikes continue to dominate, though slightly less than eastbound, with 19,882 vehicles. Public transport usage is slightly higher in this direction, with 6,320 minibuses. Commercial activity is notably lower, with only 584 trucks recorded. Interestingly, pedestrian activity increases significantly in the westbound direction, with 1,421 counts, suggesting different land use or accessibility patterns influencing travel behavior.

Directional Pattern Implications:

The modal distribution differences suggest that eastbound traffic serves more private vehicle commuters and commercial activities, while westbound traffic shows slightly higher reliance on public transport and pedestrian presence. This pattern is reflective of the fact that residential areas are located to the west and employment/commercial centers to the east, creating asymmetric commuting flows.

4.2 Peak Hour Characteristics and Temporal Patterns

A peak hour analysis conducted at the intersection of Gudele Road and Rock City Road on August 6, 2021, reveals distinct temporal traffic patterns with significant implications for

roadway capacity and operational efficiency (Fig. 10a, b &c). During the morning peak period, from 07:00 to 08:00, a total of 13,360 vehicles were recorded. The peak hour factor[3] of 0.919 indicates sustained high demand throughout the hour. Westbound traffic was the most dominant, with 5,816 vehicles—the highest single approach volume—followed by 4,387 eastbound vehicles. Northbound and southbound traffic were comparatively lower, with 1,395 and 1,762 vehicles respectively.

Insert Figures 10a, b., and c.

PERIOD	TIME	EASTBOUND	WESTBOUND	NORTHBOUND	SOUTHBOUND	TOTAL	PHF
Morning Peak	07:00–08:00	4,387	5,816	1,395	1,762	**13,360**	0.919
Evening Peak	16:15–17:15	4,154	4,266	1,402	592	**10,414**	0.968

Fig 10a. Peak Hour Analysis

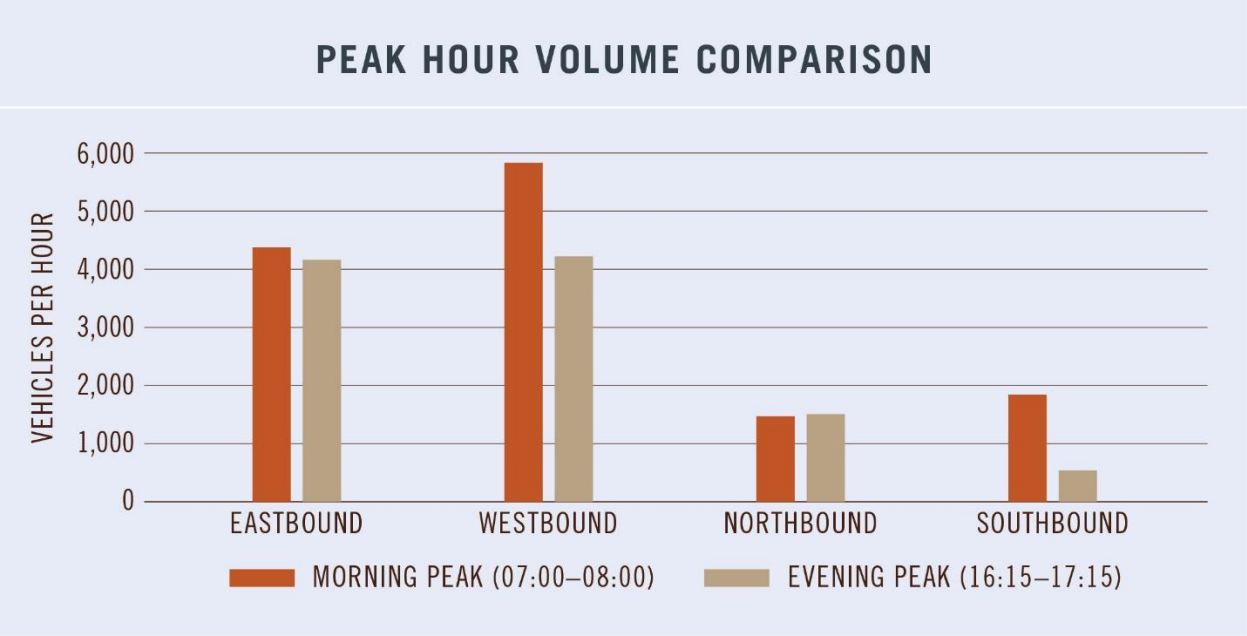


Fig 10b. Peak Hour Volume Comparison

[3] As defined in the Highway Capacity Manual, the Peak Hour Factor (PHF) is a ratio used in traffic engineering to quantify the fluctuation of traffic volume within the peak hour of the day. It indicates how evenly traffic is spread throughout that hour, with a lower PHF signifying greater variability and a higher PHF indicating more consistent traffic flow. The PHF is calculated by dividing the total hourly volume by the product of 4 and the peak 15-minute volume within that hour.

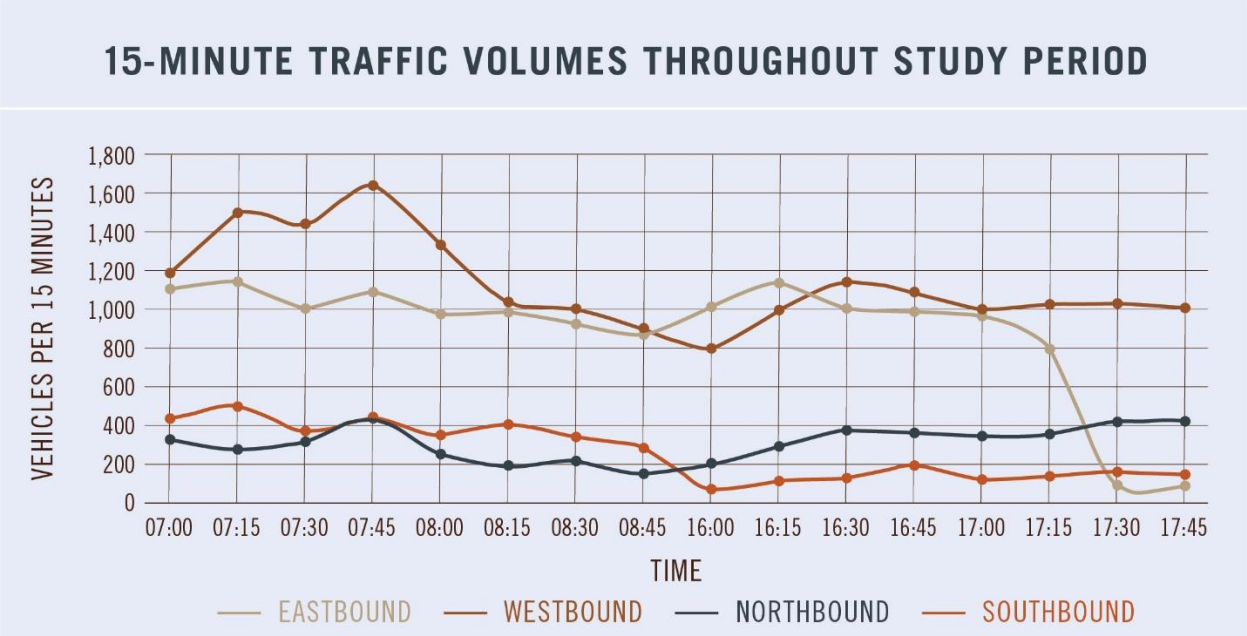


Fig 10c: 15-Minute Traffic Volumes Throughout Study Period. Peak Hour Analysis

In the evening peak period, from 16:15 to 17:15, traffic volume decreased to 10,414 vehicles, but the peak hour factor rose to 0.968, suggesting a very consistent flow pattern. Westbound and eastbound volumes remained relatively balanced, with 4,266 and 4,154 vehicles respectively. Northbound traffic held steady at 1,402 vehicles, while southbound movements dropped significantly to just 592 vehicles, indicating a notable reduction in evening travel demand in that direction.

Critical Temporal Analysis Findings:

The morning peak experiences 28% higher traffic volumes than the evening peak, indicating concentrated commuting patterns typical of employment-centered trip generation. The relatively high Peak Hour Factors (0.919-0.968) suggest consistent traffic flow throughout peak periods rather than sharp peaks, which is particularly concerning for capacity management as it indicates sustained stress rather than brief overloading.

4.3 Infrastructure Capacity Analysis

Volume-to-Capacity Assessment

An analysis using the Highway Capacity Manual (HCM) methodology reveals severe capacity constraints along Juba's primary east-west corridor (Fig. 11). Assuming standard capacities of 1,800 vehicles per hour per lane for major streets and 1,500 vehicles per hour per lane for minor streets, with two lanes in each direction, the data highlights critical operational failures during peak periods.

Insert Figure 11.

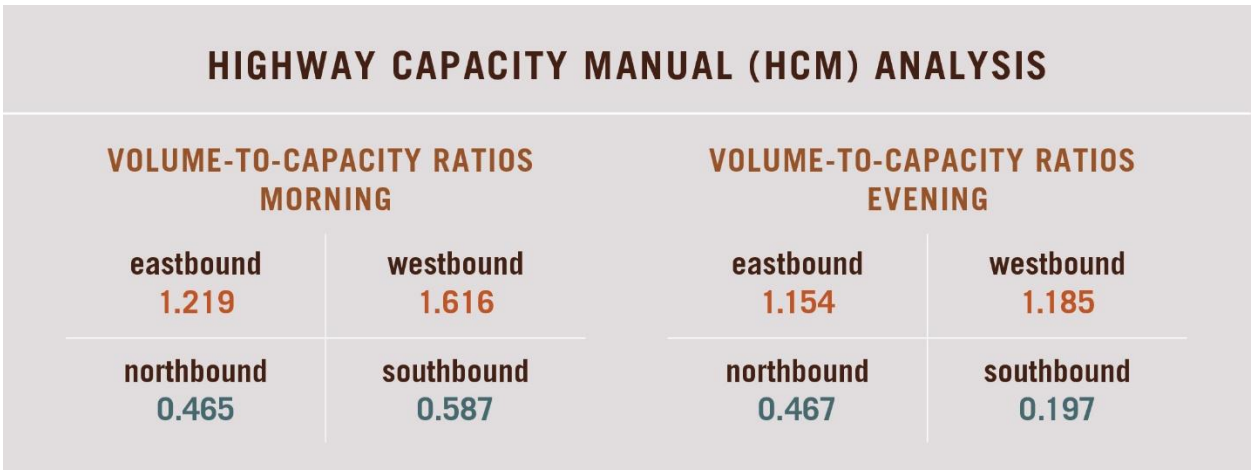


Fig 11: Highway Capacity Manual Analysis

During the morning peak hour, the volume-to-capacity (V/C) ratio for westbound traffic reached 1.616, meaning traffic exceeded capacity by 62%, while eastbound traffic had a V/C ratio of 1.219, or 122% of capacity. These figures indicate significant congestion and over-saturation in both directions. In contrast, northbound and southbound movements were well within capacity, with V/C ratios of 0.465 and 0.587 respectively.

The evening peak hour showed slightly improved but still problematic conditions. Eastbound traffic operated at 115% of capacity (V/C ratio of 1.154), and westbound at 119% (V/C ratio of 1.185), continuing the trend of overburdened infrastructure. Northbound traffic remained stable at 47% of capacity, while southbound traffic dropped sharply to just 20% of capacity, suggesting a substantial reduction in demand in that direction during the evening.

Level of Service Assessment

A Highway Capacity Manual (HCM) analysis of the intersection at Gudele Road and Rock City Road reveals stark contrasts in Level of Service (LOS), underscoring serious operational dysfunction (Fig. 12). Gudele Road, which serves as the primary east-west corridor, operates at LOS F during both morning and evening peak periods. With a total directional capacity of 3,600 vehicles per hour (based on two lanes at 1,800 vehicles per hour per lane), the morning peak demand reached 4,387 vehicles eastbound and 5,816 westbound. In the evening, demand remained high with 4,154 vehicles eastbound and 4,266 westbound. These volumes represent forced flow conditions, characterized by extreme delays and congestion. Volume-to-capacity (V/C) ratios consistently exceeded 1.0, confirming severe overcapacity and operational failure.

In contrast, Rock City Road, which runs north-south, maintained LOS A during both peak periods. With a directional capacity of 3,000 vehicles per hour (two lanes at 1,500 vehicles per hour per lane), morning peak volumes were 1,395 northbound and 1,762 southbound, while

evening volumes were 1,402 northbound and just 592 southbound. These figures indicate significant unused capacity and smooth traffic flow.

Insert Figure 12.

DIRECTION	LANES	CAPACITY (VEH/HR)	MORNING PEAK LOS	EVENING PEAK LOS
Eastbound (Gudele Road)	2	3,600	F	F
Westbound (Gudele Road)	2	3,600	F	F
Northbound (Rock City Road)	2	3,000	A	A
Southbound (Rock City Road)	2	3,000	A	A

LOS Interpretation
LOS A: Free flow conditions with minimal delays (v/c ≤ 0.60)
LOS F: Forced flow conditions with extreme delays (v/c > 1.00)
The East–West corridor is severely over capacity, operating at 121-162% of capacity during peak hours.

Fig 12: Level of Service Assessment

Overall, the analysis shows that the east-west corridor operates at 115–162% of its design capacity during peak hours, creating severe congestion and safety hazards. These findings highlight the urgent need for capacity enhancements or strategic traffic management interventions at this critical intersection.

4.4 Comprehensive Annual Road Safety Analysis

4.4.1 Annual Crash Overview and Statistical Foundation

The comprehensive safety analysis of Juba's road network reveals significant safety challenges requiring prompt attention. Crash data were obtained for the city overall, and for select major intersections. The four year data allowed for analysis of crash histories, mode, severity, and by age group of the driver.

4.4.2 Annual Crash Severity Distribution:

The detailed breakdown of crash outcomes in Juba highlights the alarming severity of the city's road safety crisis. The most frequent result of traffic incidents was minor injuries, accounting for 58 cases or 51.3% of all reported crashes. Major injuries followed, with 30 incidents (26.5%) involving substantial trauma that required intensive medical care. Property damage without human casualties was reported in 20 cases, making up 17.7% of the total. Most concerning, however, were the five fatal crashes, representing 4.4% of all incidents and underscoring the critical nature of the situation.

4.4.3 Critical Safety Metrics:

The injury rate in Juba, which stands at a staggering 77.8%—a total of 88 incidents combining both major and minor injuries—reveals that the vast majority of traffic crashes result in human

casualties. This exceptionally high rate points to multiple systemic failures contributing to the city's road safety crisis. Among the most pressing issues are inadequate vehicle safety standards and equipment, which leave drivers and passengers vulnerable during collisions. Additionally, the city's infrastructure lacks sufficient crash-protective safety design features, further exacerbating the risk of injury. Emergency medical response capabilities are also limited, reducing the chances of timely and effective treatment for crash victims. Compounding these problems are high-speed conflict scenarios involving a mix of vehicle types, which increase the likelihood and severity of accidents. Together, these factors paint a troubling picture of the road safety crisis in Juba.

4.4.4 Historical Trends (2018-2020):

Between 2018 and 2020, Juba experienced a dramatic surge in traffic incidents, underscoring a worsening road safety situation. The total number of reported incidents rose by 125%, climbing from 541 in 2018 to 1,219 in 2020. Fatalities also increased significantly, with deaths rising from 38 in 2018 to 52 in 2020—a 37% jump. Major accidents saw the most substantial growth, skyrocketing from 226 to 800 incidents, marking a 254% increase. Meanwhile, minor accidents rose from 127 to 220, reflecting a 73% increase. The year-by-year progression—541 incidents in 2018, 835 in 2019, and 1,219 in 2020—illustrates a troubling upward trend in road-related emergencies. See Figure 13.

Insert Figure 13.

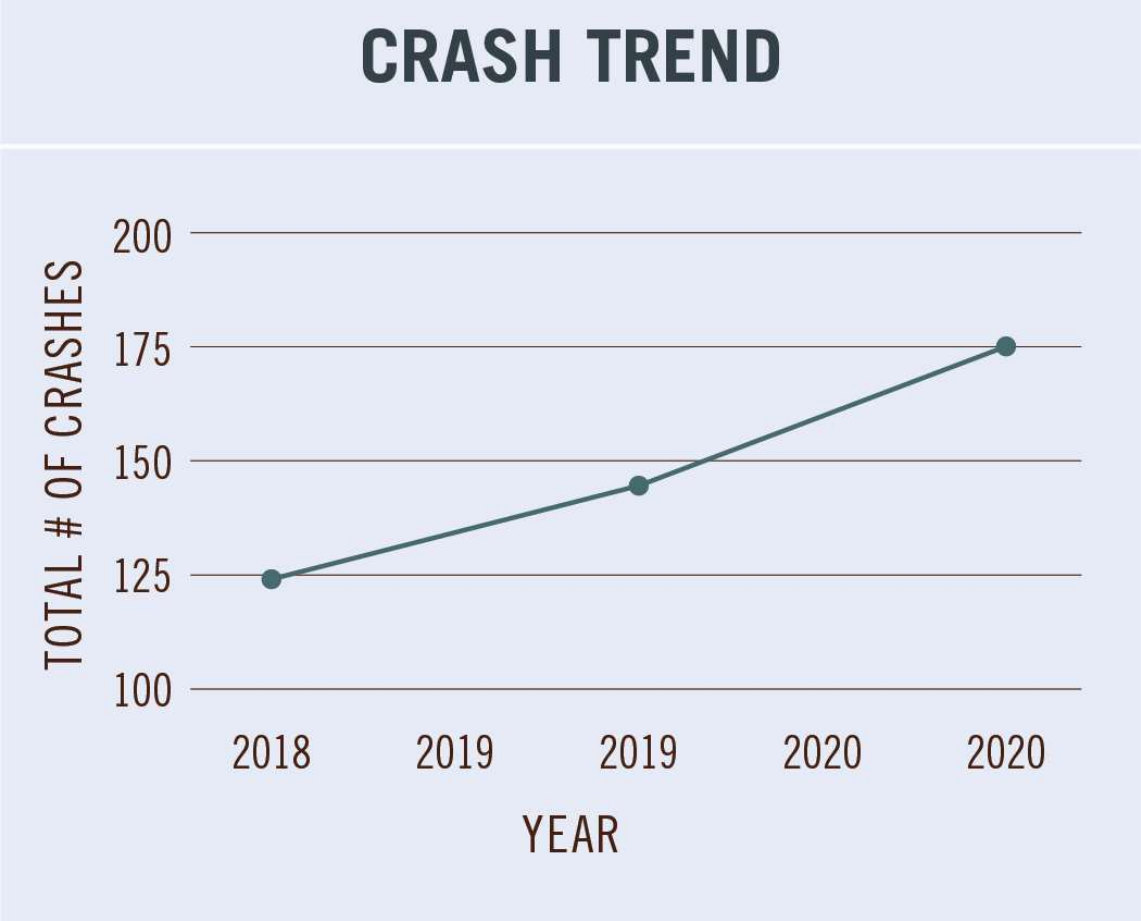


Fig 13: Crash Trend

4.4.5 Comprehensive Age-Based Risk Analysis:

A detailed demographic analysis of crash statistics from Juba, based on the age of the vehicle operator, reveals clear patterns across age groups. The highest risk demographic is the 31–35 age group, which accounted for 26 crashes—23.0% of all annual incidents. This group experienced two fatalities, seven major injuries, ten minor injuries, and seven cases of property damage, making it the category that experienced the highest percentage of crashes and significant injury severity. See Figure 14.

Insert Figure 14

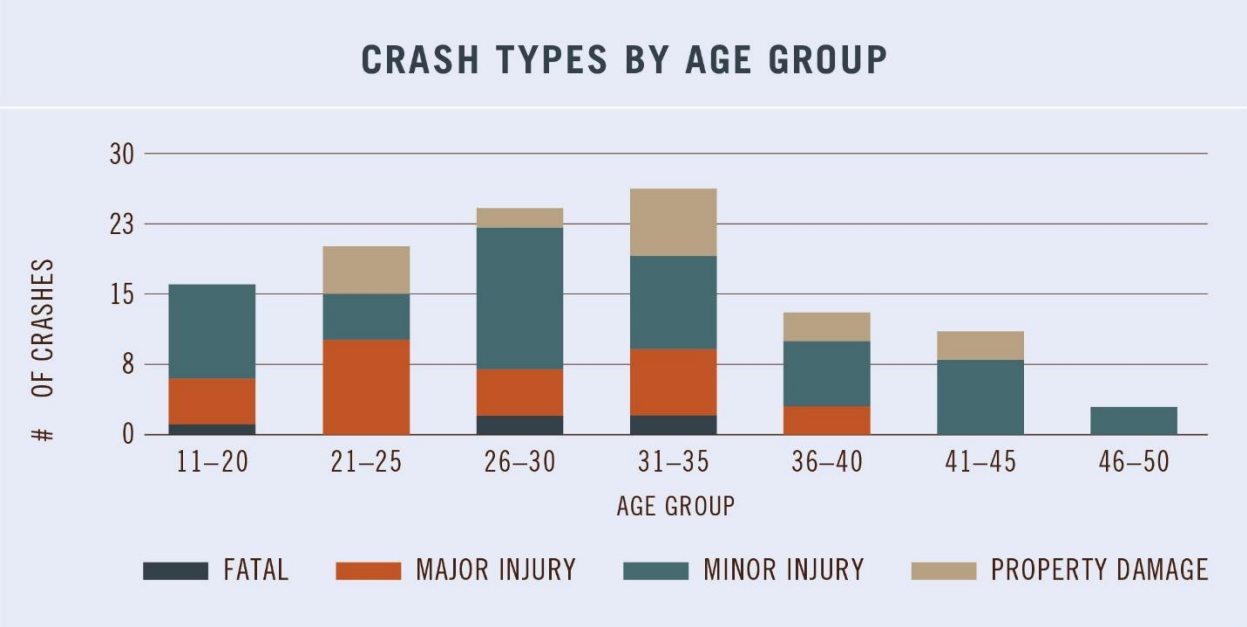


Fig 14: Crash Types by Age Group

Closely following is the 26–30 age group, which was involved in 24 crashes, representing 21.2% of all annual incidents. This group also recorded two fatalities, along with five major injuries, fifteen minor injuries, and two property damage cases. Their crash frequency and injury patterns place them also in a high-risk category.

A critical finding from the data is that drivers aged 26–35 are responsible for 44.2% of all crashes and 80% of the fatalities, identifying this demographic as the highest priority for targeted road safety interventions. Additionally, young drivers aged 21–35 are involved in the majority of the severe injuries. Notably, even the 11–20 age group shows concerning levels of crash involvement, despite likely having lower overall driving rates, suggesting broader issues in driver education and enforcement including minimum licensing age limitations that prevent minors from driving.

4.5 Intersection-Specific Safety Analysis

4.5.1 Comprehensive Comparative Roundabout Analysis (April 20-22, 2021):

The comparative analysis of Seventh Day Roundabout, Custom House Roundabout, and University of Juba Roundabouts provides critical insights into intersection safety design and management effectiveness. An analysis of a 3-day observation conducted simultaneously at all three locations reveals dramatic differences in safety performance that highlight the relationship between intersection design, traffic management, and crash patterns.

4.5.2 Seventh Day Roundabout – Critical Safety Concern Analysis

The three-day observation conducted from April 20 to 22, 2021, at the Seventh Day Roundabout revealed troubling safety conditions. During this period, four vehicles were involved in crashes, resulting in two damaged vehicles, one personal injury, and three property damage incidents. Crashes occurred on two out of the three days, yielding a 67% crash occurrence rate. The types of crashes included a rear-end collision between a truck and a car on Day 1, no incidents on Day 2, and an angular collision between two motorbikes on Day 3, which led to both vehicle damage and personal injury.

Several critical safety concerns emerged from this analysis. Motorbike vulnerability was evident, with half of the recorded crashes involving motorcycles. The angular collision on Day 3 was a right-of-way issue, highlighting the risk to both riders and vehicles. Broader trends also point to escalating severity, with major accidents increasing by 254% over just two years, indicating a deterioration in overall traffic safety. The mix of heavy vehicles such as trucks and vulnerable road users like motorbike riders creates high-risk scenarios, particularly in congested intersections. Additionally, young drivers aged 21–35 are disproportionately represented in serious crashes, emphasizing the need for targeted safety interventions.

4.5.3 University of Juba Roundabout – Critical Safety Concern Analysis

The University of Juba Roundabout exhibited even more alarming conditions. Over the same three-day period, seven vehicles were involved in four distinct crash events, resulting in five damaged vehicles, one property damage incident, and four personal injuries. Crashes occurred every day, leading to a 100% daily crash rate. This consistent pattern of incidents indicates a critical risk level and a systematic failure in intersection safety.

Vehicle type analysis across the region supports these findings, and motorcycles continue to be disproportionately involved in crashes across all age groups. The interaction between heavy vehicles and vulnerable road users remains particularly dangerous, and the high injury rates across all vehicle types is also troubling (Konlan & Hayford, 2022).

4.5.4 Custom Roundabout – Lower Risk Profile

In contrast, the Custom Roundabout demonstrated a relatively lower risk profile. During the same three-day observation period, only one crash event occurred, involving two vehicles—a motorbike and a minibus—in an angular collision on Day 2. This incident resulted in one vehicle being damaged and one personal injury, with no property damage reported. The crash occurrence rate at this location was 33%, indicating a more controlled traffic environment with isolated incidents, but the fact that at least an incident occurred at all three intersections within the short 3-day observation period underscores the risky driving environment that exists in the city of Juba.

5. Discussion

5.1 Infrastructure Capacity Implications

The capacity analysis reveals fundamental infrastructure constraints that severely limit Juba's urban mobility efficiency. The Gudele Road corridor's operation at 115-162% of design capacity during peak hours represents a critical infrastructure failure that affects economic productivity and quality of life. This overcapacity operation, combined with Level of Service F conditions, indicates that the intersection has exceeded its useful design life and requires immediate enhancement.

5.2 Motorcycle Taxi Integration Challenges and Modal Distribution Implications

The dominance of motorcycles (54.64% of traffic representing 42,681 daily movements) presents both opportunities and challenges for urban transport planning that extend far beyond simple numerical representation. The comprehensive 5-day survey data reveal the extent to which Juba's transportation system has evolved around two-wheeler mobility, creating both efficiency benefits and significant integration challenges.

The survey data showing 96.87% motorized transport (with motorcycles comprising 56.4% of that motorized total) indicates a transportation ecosystem that has evolved beyond the capacity of traditional traffic engineering solutions. The virtual absence of non-motorized alternatives (bicycles at 0.28%, pedestrians at 2.85%) means that motorcycles serve essential mobility functions that cannot be easily replaced or restricted.

5.3 Safety System Failures and Evidence-Based Analysis

The comprehensive annual crash data reveals systematic safety failures that extend beyond individual intersection problems to encompass broader transportation system inadequacies. The 77.8% injury rate across all 113 annual crashes indicates fundamental breakdowns across multiple safety domains.

The concentration of crashes among 26-35 year-olds (44.2% of all crashes and 80% of fatalities) indicates targeted intervention opportunities. This demographic represents the economically productive workforce, making road safety investments critical for broader economic development impacts.

5.4 Post-Conflict Infrastructure Development Context

Juba's transport challenges must be understood within South Sudan's broader post-conflict development trajectory. The seasonal accessibility challenges that affect most of South Sudan's road network during rainy seasons compound urban transport pressures by concentrating economic activity and population mobility in limited all-weather corridors like the Gudele Road system.

6. Conclusions

6.1 Key Findings Summary

This comprehensive analysis of Juba's urban transport system reveals a series of critical challenges that demand immediate attention. The Gudele Road corridor, a major east-west artery, operates far beyond its intended capacity, with peak hour volume-to-capacity (V/C) ratios ranging from 115% to an alarming 162%. The westbound approach during the morning peak is particularly problematic, representing the most severe operational failure.

Safety conditions are equally concerning. A staggering 77.8% of reported crashes result in injuries, pointing to systemic failures in infrastructure design, vehicle safety standards, and emergency response capabilities. Motorcycles, which make up 54.6% of the traffic, are disproportionately involved in crashes, accounting for 71% of crashes that involved vehicles, and highlighting the urgent need for motorcycle-specific infrastructure and safety measures.

Demographic analysis shows that drivers aged 26–35 are involved in 44.2% of crashes and 80% of fatalities, making them a clear priority for targeted safety education and enforcement efforts. Furthermore, the overall safety trend is deteriorating rapidly, with major accidents increasing by 254% between 2018 and 2020, underscoring the need for immediate and systematic intervention.

6.3 Research and Policy Implications

This study underscores the critical importance of evidence-based transport planning in post-conflict urban environments. The findings reveal that traditional traffic engineering approaches must be adapted to suit contexts where motorcycle taxis dominate the modal split and where rapid urban expansion consistently outpaces the capacity for infrastructure development.

Looking ahead, future research should prioritize the development of traffic management solutions that are tailored to post-conflict settings with limited institutional capacity. It is also essential to explore the connections between transport access and broader development outcomes, including economic productivity, social integration, and peacebuilding efforts. Evaluating cost-effective safety interventions that can be implemented with minimal resources yet deliver substantial public health benefits is another key area of focus. Additionally, understanding the role of informal transport systems in providing essential mobility services and identifying strategies to integrate these systems into formal transport planning will be vital for creating inclusive and resilient urban mobility frameworks.

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