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CAPACITY EVALUATION OF ROUNDABOUT JUNCTIONS ON ARTERIAL ROADS IN ILORIN.

(A Case Study of Pakata, Adeta and Mandate Roundabout Junctions)

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ABSTRACT: Rapid urbanization and increasing traffic demand have resulted in recurring congestion and reduced operational efficiency at many urban roundabouts in Nigeria. This study evaluated the operational performance of selected roundabouts in Ilorin Metropolis and assessed the effectiveness of geometric improvements in enhancing traffic flow. Peak-hour traffic volume data were collected at Pakata, Adeta, and Mandate roundabouts during the evening peak period (4:00 to 6:00pm). Roundabout entry capacities and degrees of saturation (DS) were estimated using an ARCADY-style empirical capacity model, while PTV VISSIM microscopic traffic simulation was employed to evaluate vehicular delay and

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Level of Service (LOS) under existing and proposed geometric conditions. The results showed that the existing single-lane approaches operated under oversaturated conditions, with DS values ranging from 1.30 to 6.28, indicating that traffic demand exceeded available entry capacities. These conditions resulted in excessive vehicular delays, long queues, and poor Levels of Service. A proposed redesign involving the widening of entry approaches from one lane to three lanes significantly increased entry capacities and reduced DS values to between 0.14 and 0.94 across the evaluated approaches. Simulation results further demonstrated substantial reductions in average vehicular delays and marked improvements in traffic operations and Levels of Service following the proposed geometric modifications. The combined application of the empirical capacity model and PTV VISSIM proved effective for evaluating roundabout performance and assessing improvement alternatives. The study concludes that widening roundabout entry approaches is a practical and sustainable strategy for mitigating congestion, improving traffic efficiency, and enhancing the operational performance of urban roundabouts in rapidly growing cities. The findings provide valuable guidance for transportation engineers and urban planners involved in the planning, design, and management of roundabout intersections.

Keywords: *Roundabout performance; Entry capacity; Degree of saturation; PTV VISSIM; Level of service; Traffic simulation; Geometric improvement.*

Introduction

Roundabout is a type of circular intersection designed to improve traffic flow and enhance safety by requiring vehicles to yield upon entry and circulate counter clockwise around a central island (Rafferty et al. 2015). This design reduces conflict points, particularly those associated with head-on and high-speed collisions, and encourages a smoother and more predictable traffic movement. (Rafferty et al. 2015).

Roundabouts are critical traffic control measures designed to enhance vehicular movement and minimize conflicts at intersections. Their efficiency is highly dependent on various geometric features, such as entry width, exit width, inscribed circle diameter, lane width, and approach angles. Studies have shown that geometric design significantly impacts roundabout capacity, queue length, and safety (Al-Madani, 2016; Chen & Kim, 2017). The first use of the word ‘roundabout’ appeared in the UK Ministry of Transport and Planning

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Institute Circular No.302 in 1929 as cited by (Abubakar and Ndoke, 2013). Roundabouts are common form of traffic intersection control in many urban areas. They are known to bring about certain desirable operations and safety returns. Roundabouts have distinctive operational and safety features that make them the choice for traffic control. When multiple roadways meet and form a junction, especially when volumes are moderate and distribution of traffic among the approach roads is about even, roundabouts can function efficiently and safely. When demand is high and / or not evenly distributed among entry approaches, excessive delay and aggressive driving behaviour may emerge thus compromising both operation characteristic of roundabouts (Khatib and Abu-Lebdeh, 2009). The geometric data are obtained through physical measurements of geometric features that make up the roundabout using linen tape. These include the inscribed circle diameter, approach half width, entry width, flare length, entry radius and entry angle. Figure 1. shows the key geometric features that affect the performance of a roundabout (Highway Capacity Manual, 2006). Evaluation of junction capacity is very important since it is directly related to delay, level of service, accident, operational cost and environmental issues. For more than three decades modern roundabouts have been used successfully through the world as an intersection control device (Archer, J, 2005). Capacity represents the service rate (queue clearance rate) in the performance (delay, queue length, stop rate) functions, and therefore is relevant to both under saturated and over saturated conditions (Archer, J, 2005). Conceptually, this is different from the maximum volume that the intersection can handle which is the practical capacity (based on the target degree of saturation) under increased demand volumes, not the capacity under prevailing conditions (Archer, J, 2005) Level of service is a qualitative measure used to relate the quality of traffic service. Level of service is used to analyse highways by categorizing traffic flow and assigning quality levels of traffic based on performance measure like speed, density etc (Ishant S and Pardeep K Gupta 2015).

2.0 METHODOLOGY

2.1 Description of study area

Pakata Roundabout: is located in the city of Ilorin, Kwara State, Nigeria on longitude N 8497”4.93” and latitude E 4524”6.23”. It serves as critical traffic intersection, connecting to oja oba market.

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Figure 2:1 Pakata Roundabout

Adeta Roundabout is located in the city of Ilorin, Kwara State, Nigeria on longitude N 8487”6.20” and latitude E 4517”0.22”. This roundabout serves as a critical junction connecting several roads such as al-hikmah university road. Making it a vital hub for transportation, commerce, and daily activities in the region.

Figure 2.2: Adeta Roundabout

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Mandate Roundabout: is located in the city of Ilorin, Kwara State, Nigeria on longitude N 8474”2.29” and latitude E 4502”8.16”. This roundabout is a key intersection in the city of Ilorin serving as a vital link between Adeta roundabout and Geri Alimi intersection.it is a bustling hub of activities of commerce and socio-economic zone within Ilorin.

Figure 2.3: Mandate Roundabout

2.2 Data Collection

2.1.2 Geometric Analysis of the Roundabouts

Table 1 A: Geometric Parameters of Pakata Roundabout

Approach	Entry width (m)	Radius (m)	Circumference (m)	Diameter(m)
Ita Ogumbo	2.4	7.14	42.5	14.28
Adeta	2.4	7.14	42.5	14.28
Okekere	2.4	7.14	42.5	14.28
Oke Apomu	2.0	7.14	42.5	14.28
Ita Ebo	2.1	7.14	42.5	14.28
Sakere	2.0	7.14	42.5	14.28

The capacity analysis of Pakata Roundabout reveals that, although all approaches share the same geometric characteristics (radius = 7.14 m, diameter = 14.28 m, and circumference = 42.5 m), their operational performance differs due to variations in traffic demand and

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circulating flow. Adeta Road recorded the highest entry capacity (1,036 veh/h), largely as a result of its relatively low circulating flow, while Ita-Ebo Road exhibited the lowest degree of saturation (DS = 1.43), indicating the most favourable operating condition among the approaches. In contrast, Ita-Ogumbo Road recorded the highest degree of saturation (DS = 5.90), signifying severe congestion caused by high traffic demand and substantial circulating flow. Overall, all approaches operated with degree of saturation values exceeding 1.0, indicating oversaturated conditions associated with insufficient capacity, increased vehicle delays, queue build-up, and poor Levels of Service (LOS).

Table 1 B: Geometric Parameters of Adeta Roundabout

Approach	Entry width (m)	Radius (m)	Circumference (m)	Diameter(m)
Al-Hikmah university Road	3.2	25.70	161.45	51.4
Oke Foma Road	3.0	25.70	161.45	51.4
Agbo Oba Road	2.2	25.70	161.45	51.4
Kuntu Road	2.1	25.70	161.45	51.4
Pakata Road	2.0	25.70	161.45	51.4

The capacity analysis show that, although Adeta Roundabout possesses consistent geometric features across all approaches (radius = 25.70 m, diameter = 51.4 m, and circumference = 161.45 m), its operational efficiency is largely influenced by variations in traffic demand and circulating flow. Alhikmah University Road and Oke-Foma Road experienced the highest traffic volumes and consequently recorded the highest degrees of saturation (6.28 and 5.85, respectively), indicating significant congestion and operational stress. Conversely, Kuntu Road exhibited the lowest degree of saturation (DS = 1.30), reflecting comparatively better traffic operating conditions. While the estimated entry capacities varied between 978 veh/h and 1,096 veh/h, all approaches recorded degree of saturation values exceeding the acceptable threshold of 1.0, signifying oversaturated conditions associated with inadequate capacity, substantial delays, queue accumulation, and poor Levels of Service (LOS).

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Table 1 C Geometric parameters of Mandate Roundabout

Approach	Entry width (m)	Radius (m)	Circumference (m)	Diameter(m)
Western Reservoir Road	3.1	6.75	47.45	13.49
Al-Hikmah University Road	3.2	6.75	47.45	13.49
Cails Road	2.2	6.75	47.45	13.49
Gerewu Road	2.0	6.75	47.45	13.49

The capacity analysis of Mandate Roundabout indicates that, despite the uniform geometric characteristics of the roundabout (radius = 6.75 m, diameter = 13.49 m, and circumference = 47.45 m), the operational performance of the approaches varies as a result of differences in traffic demand and circulating flow. Western Reservoir Road recorded the highest degree of saturation (DS = 4.21) and the lowest entry capacity (555 veh/h), indicating severe congestion and poor operating conditions. In contrast, Gerewu Road exhibited the lowest degree of saturation (DS = 1.50) and a relatively high capacity (941 veh/h), reflecting comparatively better traffic performance. Alhikmah University Road and Cails Road recorded moderate levels of congestion, with degrees of saturation of 2.44 and 1.57, respectively. Overall, all approaches operated with degree of saturation values exceeding 1.0, indicating oversaturated conditions characterized by inadequate capacity, increased delays, queue formation, and poor Levels of Service (LOS)

3.0 Roundabout capacity

3.1 capacity Analysis for pakata roundabout

Table 3.1 A essential data requirements for roundabout capacity Analysis for pakata roundabout

Parameter at Adeta Road	Value
Number of Lane	**1**
Left-turn flow	1419 veh/h
Right-turn flow	1344 veh/h
Through traffic	1975 veh/h

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Total Entry Flow (Q)	4738 veh/h
Circulating Flow (Qc)	126 veh/h
Capacity (C)	1036 veh/h
Degree of Saturation (DS)	4.58

The Adeta Road approach recorded a total entry flow of 4,738 veh/h and a circulating flow of 126 veh/h. The estimated capacity was 1,036 veh/h, with a Degree of Saturation (DS) of 4.58. Since the DS value is greater than 1.0, the approach is operating under oversaturated conditions, indicating severe congestion, long queues, and significant delays during peak period.

Table 3.1 B essential data requirements for roundabout capacity Analysis for pakata roundabout

Parameter at Adeta Road	**Value**
Number of Lane	**3**
Left-turn flow	1419 veh/h
Right-turn flow	1344 veh/h
Through traffic	1975 veh/h
Total Entry Flow (Q)	1579 veh/h
Circulating Flow (Qc)	126 veh/h
Capacity (C)	3107veh/h
Degree of Saturation (DS)	0.51

The Adeta Road approach was improved from a single-lane to a three-lane entry, resulting in an estimated capacity of 3,107 veh/h. With an entry flow of 1,579 veh/h, the Degree of Saturation (DS) was 0.51. This indicates that the approach operates below capacity, with stable traffic flow and minimal delays. The result demonstrates that the proposed three-lane configuration would significantly improve the operational performance of the approach and reduce congestion during peak periods.

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Table 3.1 C essential data requirements for roundabout capacity Analysis for pakata roundabout

Parameter at Ita- Ogunde Road	**Value**
Number of Lane	**1**
Left-turn flow	1605 veh/h
Right-turn flow	997 veh/h
Through traffic	840 veh/h
Total Entry Flow (Q)	3442 veh/h
Circulating Flow (Qc)	729veh/h
Capacity (C)	583veh/h
Degree of Saturation (DS)	5.90

The Ita-Ogunbo Road approach operates as a single-lane entry with a total entry flow of 3,442 veh/h and a circulating flow of 729 veh/h. The estimated capacity was 583 veh/h, resulting in a Degree of Saturation (DS) of 5.90. This indicates that the approach is operating under highly oversaturated conditions, with traffic demand far exceeding the available capacity. Consequently, severe congestion, long queues, and significant delays are expected during peak periods.

Table 3.1 D essential data requirements for roundabout capacity Analysis for pakata roundabout

Parameter at Ita- Ogunde Road	**Value**
Number of Lane	**3**
Left-turn flow	1605 veh/h
Right-turn flow	997 veh/h
Through traffic	840 veh/h
Total Entry Flow (Q)	1147 veh/h
Circulating Flow (Qc)	729 veh/h
Capacity (C)	1750 veh/h
Degree of Saturation (DS)	0.66

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Ita-Ogunbo Road approach was improved to a three-lane entry, resulting in an estimated capacity of 1,750 veh/h. With an entry flow of 1,147 veh/h, the Degree of Saturation (DS) was 0.66. This indicates that the approach operates below its available capacity and is expected to provide stable traffic flow conditions with reduced delays and queue lengths. The result demonstrates that the proposed three-lane configuration would significantly improve the operational performance of the approach and alleviate congestion during peak periods.

Table 3.1 E essential data requirements of roundabout capacity Analysis for pakata roundabout

Parameter at Okekere Road	**Value**
Number of Lane	**1**
Left-turn flow	588 veh/h
Right-turn flow	1017 veh/h
Through traffic	592 veh/h
Total Entry Flow (Q)	2197 veh/h
Circulating Flow (Qc)	227 veh/h
Capacity (C)	960 veh/h
Degree of Saturation (DS)	2.29

The Okekere Road approach operates as a single-lane entry with a total entry flow of 2,197 veh/h and a circulating flow of 227 veh/h. The estimated capacity was 960 veh/h, resulting in a Degree of Saturation (DS) of 2.29. This indicates that the approach is operating under oversaturated conditions, with traffic demand exceeding the available capacity. Consequently, congestion, long queues, and significant delays are expected during peak traffic periods.

Table 3.1 F essential data requirements of roundabout capacity Analysis for pakata roundabout

Parameter at Okekere Road	Value
Number of Lanes	3
Left-turn Flow	588veh/h
Right-turn Flow	1,017veh/h

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Through Traffic	592 veh/h
Total Entry Flow (Q)	2,197 veh/h
Circulating Flow (Qc)	227 veh/h
Capacity (C)	2,879 veh/h
Degree of Saturation (DS)	0.76

The results presented in Table 4.6.2F indicate that the Okekere Road approach at Pakata Roundabout operates under stable traffic conditions after the provision of three entry lanes. The approach recorded a left-turn flow of 588 veh/h, right-turn flow of 1,017 veh/h, and through traffic of 592 veh/h, resulting in a total entry flow of 2,197 veh/h. The circulating flow was 227 veh/h, while the estimated entry capacity based on the TRL/UK empirical model was 2,879 veh/h.

The computed Degree of Saturation (DS) of 0.76 indicates that the entry demand utilizes approximately 76% of the available capacity, leaving adequate reserve capacity to accommodate traffic fluctuations. Since the DS is less than 1.0, the approach is operating within its capacity, with stable traffic flow, acceptable delays, and minimal likelihood of persistent queuing during the peak period. These findings demonstrate that the introduction of three entry lanes has significantly improved the operational performance of the Okekere Road approach, providing sufficient capacity to meet existing traffic demand while maintaining efficient traffic operations.

Table 3.1 G essential data requirements of roundabout capacity Analysis for pakata roundabout

Parameter at Oke- Apomu Road	**value**
Number of Lane	**1**
Left-turn flow	846 veh/h
Right-turn flow	729 veh/h
Through traffic	683 veh/h
Total Entry Flow (Q)	2258 veh/h
Circulating Flow (Qc)	434 veh/h
Capacity (C)	805 veh/h
Degree of Saturation (DS)	2.81

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The Oke-Apomu Road approach operates as a single-lane entry with a total entry flow of 2,258 veh/h and a circulating flow of 434 veh/h. The estimated capacity is 805 veh/h, giving a Degree of Saturation (DS) of 2.81. This indicates that the approach is highly oversaturated, meaning traffic demand significantly exceeds the available capacity. As a result, the approach experiences heavy congestion, long queues, and considerable delays during peak periods.

Table 3.1 H essential data requirements of roundabout capacity Analysis for pakata roundabout

Parameter at Oke- Apomu Road	**value**
Number of Lane	**3**
Left-turn flow	846veh/h
Right-turn flow	729veh/h
Through traffic	683veh/h
Total Entry Flow (Q)	2258veh/h
Circulating Flow (Qc)	434 veh/h
Capacity (C)	2412veh/h
Degree of Saturation (DS)	0.94

The proposed widening of the Oke-Apomu Road approach from one lane to three lanes increased the entry capacity from 805 veh/h to 2,414 veh/h and reduced the Degree of Saturation (DS) from 2.81 to 0.94, demonstrating a substantial improvement in operational performance and indicating that the approach can adequately accommodate the prevailing traffic demand during peak periods.

Table 3.1 I essential data requirements of roundabout capacity Analysis for pakata roundabout

Parameter at Sakere Road	**value**
Number of Lane	**1**
Left-turn flow	855 veh/h
Right-turn flow	555 veh/h
Through traffic	516 veh/h
Total Entry Flow (Q)	1926 veh/h
Circulating Flow (Qc)	555 veh/h
Capacity (C)	714 veh/h
Degree of Saturation (DS)	2.70

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The Sakere Road approach recorded a total entry flow of 1,926 veh/h and a circulating flow of 555 veh/h. Using the capacity model C=1130−0.75Qc, the entry capacity was estimated as 714 veh/h, resulting in a Degree of Saturation (DS) of 2.70. This indicates that the approach is operating under highly oversaturated conditions, with traffic demand substantially exceeding the available capacity, leading to significant congestion and delays during peak periods.

Table 3.1 J essential data requirements for roundabout capacity Analysis for pakata roundabout

Parameter at Sakere Road	**value**
Number of Lane	**3**
Left-turn flow	855veh/h
Right-turn flow	555 veh/h
Through traffic	516 veh/h
Total Entry Flow (Q)	1926 veh/h
Circulating Flow (Qc)	555 veh/h
Capacity (C)	2141 veh/h
Degree of Saturation (DS)	0.90

The proposed widening of the Sakere Road approach from one lane to three lanes increased the entry capacity from 714 veh/h to 2,141 veh/h and reduced the Degree of Saturation (DS) from 2.70 to 0.90, indicating a substantial improvement in operational performance and enabling the approach to accommodate peak-hour traffic demand more efficiently.

Table 3.1 K essential data requirements for roundabout capacity Analysis for pakata roundabout

Parameter at Ita-Ebo Road	value
Number of Lane	**1**
Left-turn flow	611 veh/h
Right-turn flow	406 veh/h
Through traffic	347 veh/h
Total Entry Flow (Q)	1364 veh/h
Circulating Flow (Qc)	235 veh/h
Capacity (C)	954 veh/h
Degree of Saturation (DS)	1.43

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The Ita-Ebo Road approach operates as a single-lane entry with a total entry flow of 1,364 veh/h and a circulating flow of 235 veh/h. The estimated entry capacity is 954 veh/h, resulting in a Degree of Saturation (DS) of 1.43. Since the DS value exceeds 1.0, the approach is operating under oversaturated conditions, indicating that traffic demand exceeds the available capacity. This condition is associated with increased delays, queue formation, and reduced traffic flow efficiency during peak periods. However, compared with other approaches at Pakata Roundabout, the level of congestion is relatively lower, suggesting that the approach performs better but still requires capacity improvement to achieve satisfactory operation.

Table 3.1 L essential data requirements for roundabout capacity Analysis for pakata roundabout

Parameter at Ita-Ebo Road	value
Number of Lane	**3**
Left-turn flow	611 veh/h
Right-turn flow	406 veh/h
Through traffic	347 veh/h
Total Entry Flow (Q)	1364 veh/h
Circulating Flow (Qc)	235 veh/h
Capacity (C)	2861 veh/h
Degree of Saturation (DS)	0.48

The proposed widening of the Ita-Ebo Road approach from one lane to three lanes increased the entry capacity from 954 veh/h to 2,861 veh/h and reduced the Degree of Saturation (DS) from 1.43 to 0.48, indicating a substantial improvement in operational performance and enabling the approach to accommodate peak-hour traffic demand with minimal congestion and delay.

4.6.3 Capacity Analysis for Adeta Roundabout

3.2 capacity Analysis for Adeta Roundabout

Parameter at Al hikma University Road	value
Number of Lane	**1**
Left-turn flow	2675 veh/h
Right-turn flow	1773 veh/h

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Through traffic	1884 veh/h
Total Entry Flow (Q)	6333 veh/h
Circulating Flow (Qc)	163 veh/h
Capacity (C)	1088 veh/h
Degree of Saturation (DS)	6.28

The Alhikma University Road approach operates as a single-lane entry with a total entry flow of 6,333 veh/h and a circulating flow of 163 veh/h. The estimated entry capacity is 1,008 veh/h (approximately), resulting in a Degree of Saturation (DS) of 6.28. This indicates that the approach is operating under highly oversaturated conditions, with traffic demand far exceeding the available capacity. Consequently, severe congestion, long queues, and significant delays are expected during peak periods, suggesting that the existing lane configuration is inadequate to accommodate the prevailing traffic demand.

Table 3.2 A essential data requirements for roundabout capacity Analysis at Adeta Roundabout

Parameter at Al hikma University Road	value
Number of Lane	**3**
Left-turn flow	2675 veh/h
Right-turn flow	1773 veh/h
Through traffic	1884 veh/h
Total Entry Flow (Q)	2111 veh/h
Circulating Flow (Qc)	163 veh/h
Capacity (C)	3023 veh/h
Degree of Saturation (DS)	0.69

The proposed widening of the Alhikma University Road approach from one lane to three lanes increased the entry capacity to 3,023 veh/h, while the total entry flow was 2,111 veh/h. The resulting Degree of Saturation (DS) of 0.69 indicates that the approach operates below its available capacity and can accommodate the prevailing traffic demand efficiently. This represents a significant improvement over the existing condition, with reduced congestion, shorter queue lengths, and improved traffic flow performance during peak periods.

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Table 3.2 B essential data requirements for roundabout capacity Analysis at Adeta Roundabout

Parameter at Oke-Foma Road	value
Number of Lane	**1**
Left-turn flow	2896 veh/h
Right-turn flow	2625 veh/h
Through traffic	656 veh/h
Total Entry Flow (Q)	6177 veh/h
Circulating Flow (Qc)	101 veh/h
Capacity (C)	1054 veh/h
Degree of Saturation (DS)	5.85

The Oke Foma Road approach recorded a total entry flow of 6,177 veh/h and a circulating flow of 101 veh/h. The estimated entry capacity was 1,054 veh/h, resulting in a Degree of Saturation (DS) of 5.86. This indicates that the approach operates under highly oversaturated conditions, with traffic demand substantially exceeding the available capacity, leading to severe congestion, long queues, and significant delays during peak periods.

Table 3.2 C essential data requirements of roundabout capacity Analysis at Adeta Roundabout

Parameter at Oke-Foma Road	value
Number of Lane	**3**
Left-turn flow	2896 veh/h
Right-turn flow	2625 veh/h
Through traffic	656 veh/h
Total Entry Flow (Q)	2059 veh/h
Circulating Flow (Qc)	101 veh/h
Capacity (C)	3163 veh/h
Degree of Saturation (DS)	0.65

The proposed expansion of the Oke Foma Road approach from one lane to three lanes increased the entry capacity to 3,163 veh/h and reduced the degree of saturation to 0.65, indicating that the approach would operate below its critical capacity under peak-hour conditions. This improvement reflects a significant enhancement in operational performance, as the increased number of lanes provides additional space for vehicle

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discharge, reduces queue formation, and improves traffic circulation efficiency. Consequently, the approach is expected to experience more stable traffic flow conditions with reduced delays and a lower likelihood of congestion compared to the existing single-lane configuration.

Table 3.2 D essential data requirements of roundabout capacity Analysis at Adeta Roundabout

Parameter at Agbo-Oba	**value**
Number of Lane	**1**
Left-turn flow	623 veh/h
Right-turn flow	378 veh/h
Through traffic	470 veh/h
Total Entry Flow (Q)	1471 veh/h
Circulating Flow (Qc)	171 veh/h
Capacity (C)	1002 veh/h
Degree of Saturation (DS)	1.47

The Agbo Oba Road approach operates under a single-lane configuration with an estimated capacity of 1,002 veh/h and a degree of saturation of 1.47, indicating that the prevailing traffic demand significantly exceeds the available capacity of the approach. This condition reflects an oversaturated operational state in which the arrival flow is higher than the discharge capability of the roundabout entry. As a result, the approach experiences recurring congestion, formation of long vehicle queues, and increased delay during peak-hour periods, thereby reducing the overall efficiency and level of service of the roundabout.

Table 3.2 E essential data requirements of roundabout capacity Analysis at Adeta Roundabout

Parameter at Agbo-Oba	**value**
Number of Lane	**3**
Left-turn flow	623 veh/h
Right-turn flow	378 veh/h
Through traffic	470 veh/h
Total Entry Flow (Q)	490 veh/h

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Circulating Flow (Qc)	171 veh/h
Capacity (C)	3005 veh/h
Degree of Saturation (DS)	0.16

The proposed expansion of the Agbo Oba Road approach from one lane to three lanes increased the entry capacity to 3,005 veh/h and reduced the degree of saturation to 0.16, indicating a substantial improvement in operational efficiency. Under this condition, the approach operates well below its available capacity, resulting in free-flow traffic conditions, minimal delays, and a significant reduction in congestion during peak periods.

Table 3.2 F essential data requirements of roundabout capacity Analysis at Adeta Roundabout

Parameter at Kuntu Road	**value**
Number of Lane	**1**
Left-turn flow	530 veh/h
Right-turn flow	327 veh/h
Through traffic	418 veh/h
Total Entry Flow (Q)	1275 veh/h
Circulating Flow (Qc)	203 veh/h
Capacity (C)	978 veh/h
Degree of Saturation (DS)	1.30

The Kuntu Road approach operates as a single-lane entry with a capacity of 978 veh/h and a degree of saturation of 1.30, indicating that traffic demand exceeds the available capacity. This oversaturated condition is associated with congestion, queue formation, and increased delays during peak traffic periods.

Table 3.2 G essential data requirements for roundabout capacity Analysis at Adeta Roundabout

Parameter at Kuntu Road	**value**
Number of Lane	**3**
Left-turn flow	530 veh/h
Right-turn flow	327 veh/h
Through traffic	418 veh/h

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Total Entry Flow (Q)	425 veh/h
Circulating Flow (Qc)	203 veh/h
Capacity (C)	2933 veh/h
Degree of Saturation (DS)	0.14

The proposed expansion of the Kuntu Road approach from one lane to three lanes increased the entry capacity to 2,933 veh/h and reduced the degree of saturation to 0.14, indicating a substantial improvement in traffic operations. Under this condition, the approach operates well below capacity, resulting in minimal delays, reduced queue lengths, and efficient traffic flow during peak periods.

Table 3.2 H essential data requirements for roundabout capacity Analysis at Adeta Roundabout

Parameter at Pakata Road	**value**
Number of Lane	**1**
Left-turn flow	382 veh/h
Right-turn flow	310 veh/h
Through traffic	856 veh/h
Total Entry Flow (Q)	1548 veh/h
Circulating Flow (Qc)	46 veh/h
Capacity (C)	1096 veh/h
Degree of Saturation (DS)	1.41

The Pakata Road approach operates as a single-lane entry with an estimated capacity of 1,096 veh/h and a degree of saturation of 1.41, indicating that traffic demand exceeds the available capacity. This oversaturated condition results in congestion, increased delays, and queue formation during peak traffic periods.

Table 3.2 I essential data requirements for roundabout capacity Analysis at Adeta Roundabout

Parameter at Pakata Road	**value**
Number of Lane	**3**
Left-turn flow	382 veh/h
Right-turn flow	310 veh/h
Through traffic	856 veh/h

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Total Entry Flow (Q)	516 veh/h
Circulating Flow (Qc)	46 veh/h
Capacity (C)	3287 veh/h
Degree of Saturation (DS)	0.16

The proposed expansion of the Pakata Road approach from one lane to three lanes increased the entry capacity to 3,287 veh/h and reduced the degree of saturation to 0.16, indicating a substantial improvement in traffic operations. The approach would operate well below capacity, resulting in smoother traffic flow, reduced delays, and minimal congestion during peak-hour conditions.

4.6.4 Capacity Analysis for Mandate Roundabout

3.3 capacity Analysis for mandate roundabout

Parameter at Western Reservoir Road	**value**
Number of Lane	**1**
Left-turn flow	758 veh/h
Right-turn flow	1058 veh/h
Through traffic	518 veh/h
Total Entry Flow (Q)	2334 veh/h
Circulating Flow (Qc)	767 veh/h
Capacity (C)	555 veh/h
Degree of Saturation (DS)	4.21

The Western Reservoir Road approach operates under a single-lane configuration with a capacity of 555 veh/h and a degree of saturation of 4.21, indicating severe oversaturation. Traffic demand far exceeds the available capacity, resulting in significant congestion, long queues, and excessive delays during peak-hour periods.

Table 3.3 A essential data requirements for roundabout capacity Analysis at mandate roundabout

Parameter at Western Reservoir Road	**value**
Number of Lane	**3**
Left-turn flow	758 veh/h
Right-turn flow	1058 veh/h

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Through traffic	518 veh/h
Total Entry Flow (Q)	778 veh/h
Circulating Flow (Qc)	767 veh/h
Capacity (C)	1664 veh/h
Degree of Saturation (DS)	0.47

The proposed expansion of the Western Reservoir Road approach from one lane to three lanes increased the entry capacity to 1,664 veh/h and reduced the degree of saturation to 0.47. This improvement indicates that the approach would operate within acceptable capacity limits, resulting in smoother traffic flow, reduced delays, and improved operational performance during peak-hour conditions.

Table 3.3 B essential data requirements for roundabout capacity Analysis at mandate roundabout

Parameter at Al hikma University Road	**value**
Number of Lane	**1**
Left-turn flow	1214 veh/h
Right-turn flow	197 veh/h
Through traffic	532 veh/h
Total Entry Flow (Q)	1943 veh/h
Circulating Flow (Qc)	445 veh/h
Capacity (C)	796 veh/h
Degree of Saturation (DS)	2.44

The Al hikma Road approach operates under a single-lane configuration with a capacity of 796 veh/h and a degree of saturation of 2.44, indicating that traffic demand substantially exceeds the available capacity. This oversaturated condition results in congestion, long queues, and significant delays during peak traffic periods.

Table 3.3 C essential data requirements for roundabout capacity Analysis at mandate roundabout

Parameter at Al hikma University Road	**value**
Number of Lane	**3**
Left-turn flow	1214 veh/h

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Right-turn flow	197 veh/h
Through traffic	532 veh/h
Total Entry Flow (Q)	648 veh/h
Circulating Flow (Qc)	445 veh/h
Capacity (C)	2398 veh/h
Degree of Saturation (DS)	0.27

The proposed expansion of the Alhikma Road approach from one lane to three lanes increased the entry capacity to 2,389 veh/h and reduced the degree of saturation to 0.27. This indicates a substantial improvement in operational performance, with the approach operating well below capacity and experiencing reduced delays, shorter queues, and smoother traffic flow during peak-hour conditions.

Table 3.3 D essential data requirements for roundabout capacity Analysis at mandate.

Parameter at Gerewu Road	**value**
Number of Lane	**1**
Left-turn flow	194 veh/h
Right-turn flow	542 veh/h
Through traffic	672 veh/h
Total Entry Flow (Q)	1408 veh/h
Circulating Flow (Qc)	252 veh/h
Capacity (C)	941 veh/h
Degree of Saturation (DS)	1.50

The Gerewu Road approach operates under a single-lane configuration with a capacity of 941 veh/h and a degree of saturation of 1.50, indicating that traffic demand exceeds the available capacity. Consequently, the approach experiences oversaturated conditions characterized by congestion, queue formation, and increased delays during peak periods.

Table 3.3 E essential data requirements for roundabout capacity Analysis at mandate roundabout

Parameter at Gerewu Road	**value**
Number of Lane	**3**
Left-turn flow	194 veh/h

DOI: *10.5281/zenodo.21858171*

Right-turn flow	542 veh/h
Through traffic	672 veh/h
Total Entry Flow (Q)	469 veh/h
Circulating Flow (Qc)	252 veh/h
Capacity (C)	2823 veh/h
Degree of Saturation (DS)	0.17

The proposed expansion of the Gerewu Road approach from one lane to three lanes increased the entry capacity to 2,823 veh/h and reduced the degree of saturation to 0.17, indicating a significant improvement in operational performance. Under these conditions, the approach operates well below its available capacity, resulting in smoother traffic flow, shorter queues, and minimal delays during peak-hour periods.

Table 3.3 F essential data requirements for roundabout capacity Analysis at mandate roundabout

Parameter at Cails Road	value
Number of Lane	**1**
Left-turn flow	264 veh/h
Right-turn flow	542 veh/h
Through traffic	672 veh/h
Total Entry Flow (Q)	1478 veh/h
Circulating Flow (Qc)	252 veh/h
Capacity (C)	941 veh/h
Degree of Saturation (DS)	1.57

The Gerewu Road approach operates under a single-lane configuration with a capacity of 941 veh/h and a degree of saturation of 1.57, indicating that traffic demand exceeds the available capacity. Consequently, the approach experiences oversaturated conditions characterized by congestion, queue formation, and increased delays during peak period.

Table 3.3 G essential data requirements for roundabout capacity Analysis at mandate roundabout

Parameter at Cails Road	**value**
Number of Lane	**3**
Left-turn flow	264 veh/h
Right-turn flow	542 veh/h

DOI: *10.5281/zenodo.21858171*

Through traffic	672 veh/h
Total Entry Flow (Q)	493 veh/h
Circulating Flow (Qc)	252 veh/h
Capacity (C)	2823 veh/h
Degree of Saturation (DS)	0.17

The proposed expansion of the Gerewu Road approach from one lane to three lanes increased the entry capacity to 2,823 veh/h and reduced the degree of saturation to 0.17, indicating a significant improvement in operational performance. Under this condition, the approach operates well below its available capacity, resulting in smoother traffic flow, shorter queues, and minimal delays during peak-hour periods

3.4 delay studies

PAKATA ROUNDABOUT GRAPHICAL RESULTS ANALYSIS

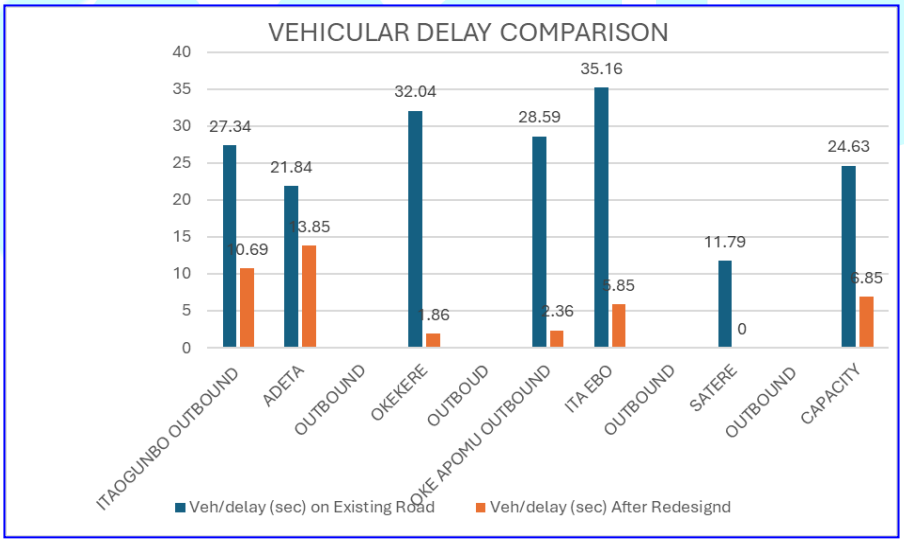

Figure 3.4 A: vehicular delay comparison on existing intersection and after intersection width expansion at Pakata Roundabout.

Figure 3.4 A represent vehicular delay comparison on existing intersection and after intersection width expansion, comparing the average vehicular delay at Pakata Roundabout under the existing intersection geometry and after the intersection width expansion. The results show that increasing the intersection width reduced vehicular delay across all approaches by improving entry capacity and traffic circulation. Consequently, the degree of saturation decreased, leading to improve and a better capacity of the roundabout during the peak hour

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ADETA ROUNDABOUT GRAPHICAL RESULTS ANALYSIS

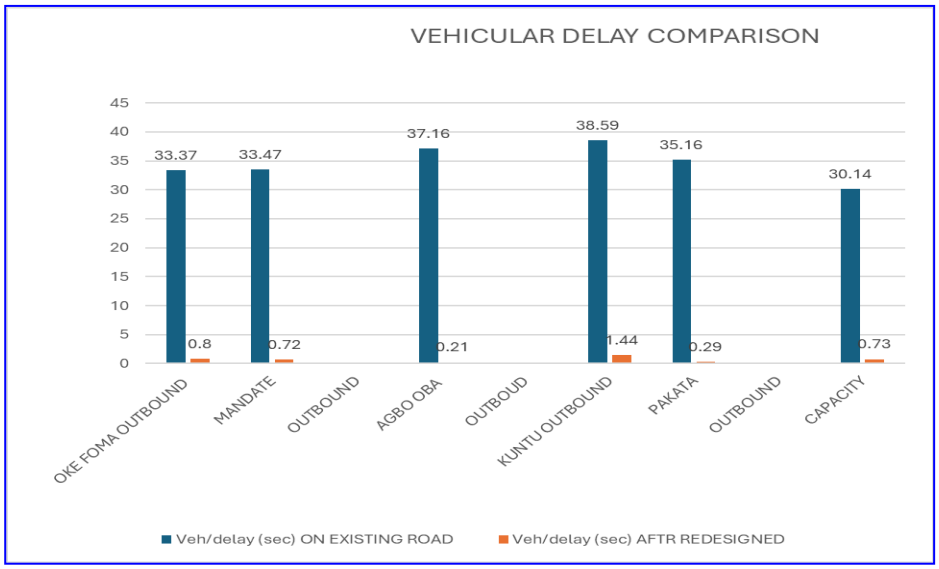

Figure 3.4 B: vehicular delay comparison on existing intersection and after intersection width expansion Adeta Roundabout.

Figure 3.4 B presents a comparison of vehicular delays at Adeta Roundabout under the existing intersection geometry and after the proposed intersection width expansion. The results indicate that the proposed widening reduced average vehicular delays by increasing the entry capacity and improving traffic movement through the roundabout. This reduction in delay reflects improved traffic operations, lower congestion levels, and an enhanced the capacity during the peak hour.

MANDATE ROUNDABOUT GRAPHICAL RESULTS ANALYSIS

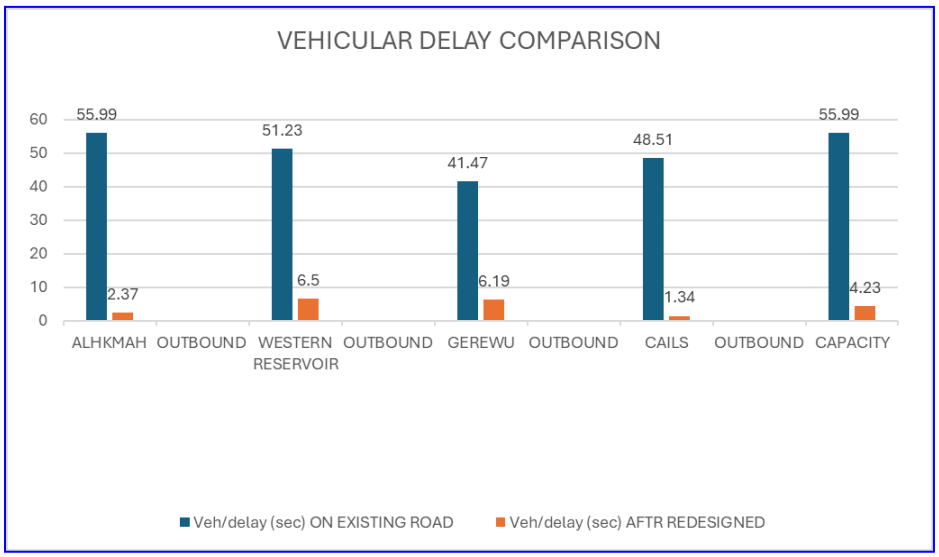

Figure 3.4 C vehicular delay comparison on existing intersection and after intersection width expansion.

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Figure 3.4 C compares the average vehicular delay at Mandate Roundabout under the existing geometry and after the proposed intersection width expansion. The results demonstrate that widening the intersection reduced vehicular delays by increasing entry capacity and improving traffic circulation. Therefore, the roundabout experienced improved in the capacity during the peak hour, reduced congestion.

Conclusion

This study evaluated the operational performance of four selected roundabouts in Ilorin Metropolis Pakata, Adeta, and Mandate Roundabouts using the ARCADY-style linear capacity model and PTV VISSIM microscopic traffic simulation. This model was employed to estimate the entry capacity and degree of saturation of each approach, while PTV VISSIM was used to simulate traffic operations and evaluate vehicular delay and Level of Service (LOS) under both existing and proposed geometric conditions. The analyses were based on peak-hour traffic data collected between 4:00 p.m. and 6:00 p.m.

The results from the model empirical capacity analysis revealed that the existing single-lane roundabout approaches were operating under oversaturated conditions, with degree of saturation values exceeding the acceptable limit of 1.0 on most approaches. These conditions indicate that traffic demand exceeded the available entry capacity, resulting in poor operational performance. The analysis further showed that approaches with higher circulating flows generally recorded lower entry capacities and higher degrees of saturation.

The PTV VISSIM simulation results corroborated the findings of the ARCADY-style linear capacity model by demonstrating high vehicular delays and poor Levels of Service under the existing geometric conditions. Following the proposed widening of the roundabout approaches from one lane to three lanes, the simulation showed a substantial reduction in vehicular delays and significant improvements in traffic operations. Similarly, the ARCADY-style linear capacity model analysis indicated increased entry capacities and reduced degrees of saturation, confirming that the proposed geometric improvements enhanced the operational efficiency of the selected roundabouts.

Overall, the findings demonstrate that the integration of the model empirical capacity model with PTV VISSIM simulation provides a comprehensive approach for evaluating

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roundabout performance. The study concludes that widening the entry approaches is an effective traffic management strategy capable of increasing capacity, reducing congestion and vehicular delays, improving the Level of Service, and enhancing the overall operational performance of urban roundabouts in Ilorin Metropolis.

Recommendations

To maintain and further enhance the improved traffic conditions, the following recommendations are proposed:

Width expansion should be sustained and properly maintained along Adeta Road, Ita Ogunbo Road, Okekere Road, Ita Ebo Road, Sakere Road, Western Reservoir Road, Cails Road, Gerewu, and Alhikma Road to accommodate present and future traffic demand.

On-street parking, street hawking, and encroachment of kiosks on road pavements should be strictly prohibited, as they reduce the effective carriageway width and negatively impact traffic flow.

Traffic management agencies should integrate traffic micro-simulation tools into planning and policy formulation for better evaluation of proposed traffic interventions.

Adequate road markings, traffic signs, and channelization should be introduced to improve driver guidance and enhance safety at the intersection.

Routine traffic monitoring and evaluation should be conducted to ensure that the intersection continues to operate at an acceptable Level of Service as traffic demand increases.

Enforcement of traffic regulations and public awareness campaigns should be strengthened to minimize violations and improve overall road user behaviour.

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