

Traffic Demand Disruption and Highway Resilience in Southeastern Nigeria: A Multicorridor Analysis of Annual Traffic Patterns

Henry Ugwuanyi

henrykene9@gmail.com

Michael Okpara University of Agriculture, Umudike

Fidelis Okafor

Michael Okpara University of Agriculture, Umudike

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Abstract

Understanding fluctuations in traffic demand is fundamental to effective highway planning, infrastructure management, and transportation-system resilience, especially in regions characterized by limited long-term traffic data. This study investigates annual traffic-demand patterns and disruption responses across five major highway corridors in Southeastern Nigeria using 100 corridor-year observations covering 2001–2020. The corridors comprise Umuahia–Ikot Ekpene, Onitsha–Owerri, Abakaliki–Ogoja, Enugu–Port Harcourt and Owerri–Port Harcourt. Annual average daily traffic (AADT) was examined through longitudinal descriptive analysis, corridor-level comparison and disruption-response indicators. Particular attention was given to the 2019–2020 transition, which coincided temporally with the COVID-19 pandemic and major movement restrictions in Nigeria. The results show substantial and persistent heterogeneity in traffic demand among the five corridors. Mean AADT was highest on Enugu–Port Harcourt (2,202,095 PCU/day) and lowest on Abakaliki–Ogoja (588,709 PCU/day). The pooled annual mean declined from 1,641,919 PCU/day in 2019 to 808,602 PCU/day in 2020, a reduction of approximately 50.8%. Corridor-specific reductions ranged from 40.9% on Umuahia–Ikot Ekpene to 66.3% on Owerri–Port Harcourt. The results demonstrate that the observed traffic-demand disruption was spatially heterogeneous. A traffic-demand retention ratio was used to describe the resistance dimension of highway resilience, while complete recovery was not estimated because the available series ends in 2020. The findings provide empirical evidence for corridor-specific resilience planning and highlight the importance of maintaining continuous traffic monitoring and disruption-sensitive highway management in data-constrained transportation systems.

1. INTRODUCTION

Annual average daily traffic (AADT) is a fundamental measure of roadway use because it provides a standardized representation of traffic volume over a year and supports highway planning, traffic management, pavement assessment and transportation investment. The Federal Highway Administration defines AADT as the total annual traffic volume divided by 365 and emphasizes appropriate traffic-monitoring procedures for deriving representative annual values (Federal Highway Administration [FHWA], 2022). AADT estimation research also shows that traffic conditions are associated with roadway, socioeconomic and land-use characteristics and that spatial heterogeneity should be considered when traffic observations are extrapolated across road networks (Sfyridis & Agnolucci, 2020).

Beyond routine traffic estimation, observed traffic demand can provide evidence about how transportation systems respond to disruptive events. Transportation resilience has been conceptualized in terms of the ability of a system to withstand, absorb, adapt to and recover from disruptions while maintaining or restoring essential functions (Bruneau et al., 2003; Gonçalves & Ribeiro, 2020; Pan et al., 2021). Contemporary reviews emphasize that resilience assessment is highly dependent on the nature of the disruption, the performance indicator selected and the reference condition against which change

is measured (Serdar et al., 2022). Empirical-data studies further highlight the importance of spatial variation and real-world performance data in resilience assessment (Bergantino et al., 2024).

Traffic demand is particularly useful for disruption analysis because abrupt changes in vehicle activity can indicate changes in mobility, economic activity, accessibility and route use. The resilience literature increasingly recognizes performance-based measures and distinguishes disruption effects from subsequent recovery trajectories (Bruneau et al., 2003; Serdar et al., 2022). Road-network resilience research also indicates that infrastructure investment, network planning and recovery arrangements can affect the capacity of road systems to maintain or restore functionality after disruption (Liu et al., 2023).

The COVID-19 pandemic provides a particularly relevant disruption context. International transportation research documented large changes in travel demand during the pandemic, while Nigerian studies reported substantial transportation impacts associated with restrictions, changes in mobility and altered travel behaviour (Mogaji, 2020; Okeke et al., 2023). In Nigeria, federal directives in 2020 restricted non-essential interstate passenger travel and introduced other movement-control measures, although controlled movement of goods and essential services was permitted (Federal Ministry of Information and National Orientation, 2020a, 2020b). These measures provide important contextual evidence for interpreting the abrupt traffic reduction observed in the present dataset.

Despite increasing interest in transport resilience, empirical evidence remains limited for long-term, multicorridor highway traffic response in Southeastern Nigeria. Existing Nigerian COVID-19 transportation studies have often focused on transport operators, urban transportation or individual locations rather than long-term annual AADT series spanning multiple inter-state corridors (Mogaji, 2020; Okeke et al., 2023). This study addresses that gap by using two decades of annual traffic observations to examine both persistent corridor-level differences and the spatially heterogeneous traffic-demand response associated with the 2019–2020 disruption.

1.1 AIM AND OBJECTIVES

The aim is to examine long-term annual traffic patterns and the observed disruption response of selected inter-state highway corridors in Southeastern Nigeria.

1. characterize annual AADT patterns across the five selected highway corridors from 2001 to 2020;
2. quantify persistent differences in traffic demand among the corridors;
3. measure the magnitude of the 2019–2020 traffic-demand disruption;
4. compare corridor-specific traffic-demand retention during the observed disruption; and
5. discuss the implications of the observed patterns for highway resilience, traffic monitoring and infrastructure planning.

1.2 RESEARCH CONTRIBUTION

The study differs from predictive AADT research because its principal question is not how accurately future traffic can be predicted, but how annual traffic demand varies across corridors and how that demand changes during a major observed disturbance. The contribution is therefore empirical and resilience-oriented: it combines a 20-year multicorridor AADT record with a transparent disruption metric and a corridor-level comparison of traffic-demand retention. This emphasis responds to calls for greater use of real-world data and spatially differentiated evidence in transportation-resilience research (Bergantino et al., 2024).

2. CONCEPTUAL FRAMEWORK

Resilience is treated in this study as a multidimensional concept rather than as a single numerical property. Following the established resilience literature, a transportation system may be considered more capable of withstanding disruption when it experiences a smaller loss of function and/or restores function more rapidly (Bruneau et al., 2003; Gonçalves & Ribeiro, 2020). Because the available AADT series terminates in 2020, the present study operationalizes only the observed resistance dimension of resilience. It does not claim to estimate full recovery or long-term resilience.

Two indicators are used:

Traffic-demand disruption (TDD):

$$TDD_i = \frac{(AADT_{2020,i} - AADT_{2019,i})}{AADT_{2019,i}} \times 100$$

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Where;

DR_i = traffic-demand retention ratio for corridor i ;

$AADT_{2020,i}$ = AADT during the disruption year; and

$AADT_{2019,i}$ = AADT immediately preceding the disruption

Traffic-demand retention ratio (TDRR):

$$TDRR_i = \frac{AADT_{2020,i}}{AADT_{2019,i}} \times 100$$

2

A negative TDD indicates a reduction in annual traffic demand, whereas a higher TDRR indicates a larger proportion of the pre-disruption traffic level retained in 2020. These indicators are descriptive measures

of observed response and should not be interpreted as complete resilience scores because recovery time, network redundancy and other dimensions of resilience are not observed in the dataset.

3. MATERIALS AND METHODS

3.1 Study Area And Observational Structure

The analysis covers five inter-state highway corridors in Southeastern Nigeria: Umuahia–Ikot Ekpene in Abia State, Onitsha–Owerri in Anambra State, Abakaliki–Ogoja in Ebonyi State, Enugu–Port Harcourt in Enugu State, and Owerri–Port Harcourt in Imo State. Each corridor contributes 20 annual observations from 2001 through 2020, producing a balanced dataset of 100 corridor-year observations.

The selected highway corridors were chosen to provide spatially diverse representations of inter-state traffic conditions across the five southeastern Nigerian states included in the study. Table 1 presents the corridors and their functional roles, ranging from comparatively lower-traffic inter-state routes to major commercial corridors with high traffic demand.

Table 1
Selected highway corridors and their study roles

State	Highway corridor	Functional description
Abia	Umuahia–Ikot Ekpene	Inter-state arterial corridor
Anambra	Onitsha–Owerri	High-demand commercial/inter-state corridor
Ebonyi	Abakaliki–Ogoja	Inter-state corridor with comparatively lower traffic scale
Enugu	Enugu–Port Harcourt	Major high-volume inter-state/commercial corridor
Imo	Owerri–Port Harcourt	Major inter-state/commercial corridor

The Enugu–Port Harcourt corridor represents the major high-volume route in the study, reflecting its strategic role in connecting important commercial and economic centres within the region. The Onitsha–Owerri and Owerri–Port Harcourt corridors also serve important commercial and inter-state functions, while the Umuahia–Ikot Ekpene and Abakaliki–Ogoja corridors provide representation of inter-state routes with comparatively lower traffic intensity. This variation in corridor function and traffic scale provides an appropriate basis for examining how socioeconomic, environmental and highway-supply characteristics influence inter-state traffic demand across different transport settings.

3.2 Data Sources And Variables

The analytical dataset contains 100 highway-year observations. Historical traffic observations were compiled from the Federal Road Safety Corps (FRSC); rainfall data were obtained from the Nigerian Meteorological Agency (NiMet); socioeconomic information was sourced from the National Bureau of

Statistics (NBS); and pothole information was derived from road-condition/maintenance records within the study framework. AADT is expressed in passenger-car units per day (PCU/day).

Table 2 presents the principal variables incorporated into the multicorridor analysis and specifies their respective analytical roles and measurement units. The variables were selected to capture traffic demand, socioeconomic conditions, demographic characteristics, environmental influences, highway condition and temporal effects across the study corridors..

Table 2
Principal variables used in the multicorridor analysis

Variable	Analytical role	Measurement/interpretation
AADT	Dependent variable	Annual average daily traffic, PCU/day
GDP	Economic context	State-level economic activity indicator
Passenger population density	Demographic context	Population/travel-demand indicator used in the study dataset
Annual rainfall	Environmental context	Annual precipitation, mm
Pothole volume	Highway condition	Pavement-distress indicator, m ³ /km
Year	Temporal context	Calendar year, 2001–2020

AADT serves as the dependent variable, while GDP and passenger population density represent socioeconomic and demographic demand drivers, rainfall and pothole volume capture environmental and highway-condition influences, and year accounts for systematic temporal changes over the 2001–2020 study period.

3.3 Analytical Procedures

Descriptive statistics were used to characterize the pooled AADT distribution and corridor differences. Annual regional means were calculated by averaging the five corridor observations in each year. The 2019–2020 period was then examined separately because the dataset contains a pronounced discontinuity in 2020. Corridor-specific percentage changes and retention ratios were calculated from the observed 2019 and 2020 AADT values.

Pearson and Spearman correlations were retained as supporting analyses because the broader dataset includes economic, demographic, environmental and pavement-condition variables. Pearson correlation summarizes linear association, whereas Spearman correlation assesses monotonic association. The correlations are used descriptively and are not interpreted as evidence of causality.

To maintain temporal integrity, the study does not treat the 2020 observation as an ordinary continuation of the pre-2020 trend. This is important because resilience research emphasizes reference conditions and temporal changes in performance during disruption (Serdar et al., 2022).

4. RESULTS

4.1 Overall AADT Characteristics

Table 3 presents the descriptive statistics of the principal study variables based on 100 observations covering the five selected highway corridors over the 2001–2020 study period.

Table 3
Descriptive statistics of the principal study variables

Variable	N	Mean	SD	Minimum	Maximum
AADT (PCU/day)	100	1,313,110.42	569,491.41	364,259.00	2,733,585.00
GDP	100	48,335,314.03	25,776,758.33	14,000,000.00	102,200,000.00
Passenger population density	100	8,510,189.59	5,811,887.28	1,116,000.00	31,216,103.00
Annual rainfall (mm)	100	2,460.20	466.73	1,641.00	3,637.00
Pothole volume (m ³ /km)	100	1.21	0.78	0.33	4.03

AADT recorded a mean of 1,313,110.42 PCU/day with substantial variation (SD = 569,491.41), ranging from 364,259 to 2,733,585 PCU/day, while GDP and passenger population density also exhibited considerable dispersion across the observations. Annual rainfall averaged 2,460.20 mm and ranged from 1,641 to 3,637 mm, whereas pothole volume averaged 1.21 m³/km with values between 0.33 and 4.03 m³/km, indicating substantial variation in environmental exposure and highway-condition characteristics across the study corridors.

4.2 Corridor Heterogeneity

Table 4 summarises the corridor-level distribution of AADT across the five selected highways over the 2001–2020 study period, highlighting differences in traffic magnitude and variability.

Table 4
Corridor-level AADT characteristics, 2001–2020

Highway corridor	Mean AADT	SD	Minimum	Maximum
Umuahia–Ikot Ekpene	1,226,869	203,114	911,316	1,555,769
Onitsha–Owerri	1,273,647	216,380	897,216	1,684,165
Abakaliki–Ogoja	588,709	186,234	364,259	1,026,650
Enugu–Port Harcourt	2,202,095	357,844	1,263,635	2,733,585
Owerri–Port Harcourt	1,274,232	209,153	533,476	1,581,339

Enugu–Port Harcourt had the highest mean AADT at 2,202,095 PCU/day, whereas Abakaliki–Ogoja had the lowest at 588,709 PCU/day. The difference between these corridor means is approximately 1.61 million PCU/day. Owerri–Port Harcourt and Onitsha–Owerri had almost identical mean traffic levels, differing by only about 585 PCU/day. These results indicate that corridor identity is an important component of the observed traffic-demand structure.

Figure 1 illustrates the mean AADT across the five selected highway corridors during the 2001–2020 study period.

The Enugu–Port Harcourt corridor recorded the highest mean AADT (2,202,095 PCU/day), substantially exceeding the other corridors, while Abakaliki–Ogoja had the lowest mean AADT (588,709 PCU/day). The marked differences in average traffic demand highlight substantial corridor-level heterogeneity, reflecting differences in commercial activity, population concentration, connectivity and the functional importance of the respective inter-state highways.

Figure 2 illustrates the mean annual average daily traffic (AADT) recorded across the five selected highway corridors over the 2001–2020 study period.

The Enugu–Port Harcourt corridor recorded the highest mean AADT (2,202,095 PCU/day), followed by Owerri–Port Harcourt (1,274,232 PCU/day), Onitsha–Owerri (1,273,647 PCU/day), and Umuahia–Ikot Ekpene (1,226,869 PCU/day), while Abakaliki–Ogoja recorded the lowest mean value (588,709 PCU/day). The substantial differences in mean traffic demand indicate pronounced corridor-level heterogeneity, which may reflect variations in economic activity, population concentration, connectivity, and the strategic functional roles of the respective highways.

4.3 Longitudinal Traffic-Demand Pattern

Building on the corridor-level differences presented in Fig. 2, Table 5 provides a complementary temporal perspective by showing the annual mean AADT across the five highway corridors from 2001 to 2020. The table therefore illustrates how overall traffic demand evolved over time, highlighting the progressive changes in mean AADT and the pronounced decline observed in 2020. This temporal pattern provides a basis for examining the growth, fluctuations and potential disruption in highway traffic demand during the study period.

Table 5
Annual mean AADT across the five
highway corridors

Year	Mean AADT (PCU/day)
2001	1,190,169
2002	1,246,169
2003	1,194,908
2004	1,269,410
2005	1,274,405
2006	1,098,075
2007	1,154,626
2008	1,184,429
2009	1,249,793
2010	1,342,830
2011	1,326,862
2012	1,189,517
2013	1,444,398
2014	1,533,524
2015	1,486,561
2016	1,562,227
2017	1,524,251
2018	1,539,535
2019	1,641,919
2020	808,602

The annual regional mean AADT increased from 1,190,169 PCU/day in 2001 to 1,641,919 PCU/day in 2019, although the trajectory was not monotonic. A notable decline occurred in 2006 and another in 2012, followed by renewed increases. The most pronounced discontinuity occurred in 2020, when mean AADT fell to 808,602 PCU/day. Thus, the 2020 value was approximately 50.8% below the 2019 level.

Figure 3 illustrates the corridor-specific changes in mean AADT between 2019 and 2020, highlighting the extent of traffic-demand disruption across the five study highways.

Figure 3 illustrates the magnitude and corridor-specific pattern of traffic-demand disruption between 2019 and 2020, providing evidence of a pronounced contraction in inter-state highway activity across the study area. Mean AADT declined on all five corridors, with the largest reduction occurring on Owerri–Port Harcourt (66.3%), followed by Abakaliki–Ogoja (57.8%), Enugu–Port Harcourt (48.9%), Onitsha–Owerri (43.3%), and Umuahia–Ikot Ekpene (40.9%), indicating that the disruption was widespread but varied substantially in intensity across corridors. This heterogeneous response suggests that the 2020 traffic shock did not affect highway demand uniformly, but was conditioned by differences in corridor function, commercial dependence, mobility intensity and network connectivity, with the sharper declines pointing to greater sensitivity of some routes to mobility restrictions and disruptions in economic activity.

4.4 Corridor-Specific Disruption And Traffic-Demand Retention

Building on the corridor-level disruption patterns shown in Fig. 3, Table 6 quantifies the magnitude of traffic-demand loss between 2019 and 2020 and further expresses the disruption through the retention ratio for each highway corridor.

Table 6 Corridor-specific traffic-demand disruption and retention, 2019–2020					
Highway corridor	2019 AADT	2020 AADT	Absolute change	Disruption	Retention ratio
Umuahia–Ikot Ekpene	1,541,130	911,316	-629,814	-40.9%	59.1%
Onitsha–Owerri	1,589,349	901,601	-687,748	-43.3%	56.7%
Abakaliki–Ogoja	1,026,650	432,982	-593,668	-57.8%	42.2%
Enugu–Port Harcourt	2,471,127	1,263,635	-1,207,492	-48.9%	51.1%
Owerri–Port Harcourt	1,581,339	533,476	-1,047,863	-66.3%	33.7%

The results confirm that all five corridors experienced substantial reductions in AADT, with the largest absolute declines occurring on Enugu–Port Harcourt (– 1,207,492 PCU/day) and Owerri–Port Harcourt (– 1,047,863 PCU/day), while the retention ratios ranged from 33.7% on Owerri–Port Harcourt to 59.1% on Umuahia–Ikot Ekpene. These findings strengthen the evidence of heterogeneous traffic-demand disruption identified in Fig. 3, showing that although the shock was region-wide, its severity differed markedly among corridors, with commercially intensive and highly connected routes such as Owerri–Port Harcourt exhibiting particularly low traffic retention. However, the retention ratios should not be interpreted as complete resilience rankings because resilience also includes recovery, adaptation, redundancy and other dimensions that are not observed in this annual dataset (Bruneau et al., 2003; Bergantino et al., 2024).

Figure 4 compares annual average daily traffic (AADT) levels before and during the observed disruption, extending the corridor-specific evidence presented in Figs. 2 and 3 and Table 6.

The figure shows a marked contraction in traffic demand during 2020 following the relatively higher AADT levels recorded in the preceding years, consistent with the substantial corridor-level reductions of 40.9% to 66.3% reported in the earlier results. The sharp decline provides further evidence of a widespread but heterogeneous traffic-demand shock, demonstrating that the observed disruption represented a substantial departure from the prevailing traffic pattern rather than a continuation of the long-term AADT trend.

4.5 Correlation Structure

Table 7 presents the Pearson and Spearman correlation coefficients between AADT and the principal explanatory variables, providing further evidence on the factors associated with the corridor-level traffic patterns identified in the preceding results.

Table 7
Pearson and Spearman correlations with AADT

Predictor	Pearson r	Spearman p
Passenger population density	0.791	0.819
GDP	0.676	0.526
Rainfall	0.501	0.576
Pothole volume	0.307	0.450
Year	0.141	0.203

Passenger population density exhibited the strongest positive association with AADT under both Pearson ($r = 0.791$) and Spearman ($p = 0.819$) measures, followed by GDP ($r = 0.676$; $p = 0.526$), indicating that demographic concentration and economic activity are important correlates of inter-state traffic demand. Rainfall showed a moderate positive association with AADT ($r = 0.501$; $p = 0.576$), while pothole volume displayed a weaker relationship ($r = 0.307$; $p = 0.450$), suggesting that environmental and highway-condition factors may influence traffic demand but less strongly than socioeconomic factors. The relatively weak association between year and AADT ($r = 0.141$; $p = 0.203$) is also noteworthy because, despite the longer-term temporal variation shown in Table 5, the pronounced 2020 disruption identified in Figs. 3, 4 and Table 6 indicates that changes in traffic demand were not adequately explained by a simple linear time trend alone.

The Pearson–Spearman differences in Table 7 are important because the two coefficients assess association in different ways:

1. Pearson correlation (r) measures the strength and direction of a linear relationship between AADT and each predictor. It is therefore more sensitive to whether increases in a predictor are associated

with proportional, approximately linear increases or decreases in AADT.

2. Spearman correlation (ρ) is a rank-based, non-parametric measure. It evaluates whether the relationship is generally monotonic, meaning that higher values of a predictor tend to correspond to higher or lower AADT, without requiring the relationship to be strictly linear.

Table 8
Pearson and Spearman correlation analysis of AADT and explanatory variables

Predictor	Pearson r	Spearman ρ	Interpretation
Passenger population density	0.791	0.819	Very strong positive association; the slightly higher Spearman value suggests a strong monotonic relationship that may not be perfectly linear.
GDP	0.676	0.526	Pearson is considerably higher, suggesting that the association is stronger in linear terms than in overall rank ordering and may be influenced by the scale or distribution of the observations.
Rainfall	0.501	0.576	Spearman is higher, indicating a moderately positive monotonic relationship that may contain some non-linearity or departures from a strictly linear pattern.
Pothole volume	0.307	0.450	The higher Spearman coefficient suggests a stronger monotonic association than the linear Pearson measure captures, possibly reflecting a non-linear relationship.
Year	0.141	0.203	Weak positive association under both measures, confirming that time alone has limited explanatory association with AADT.

Table 8 presents the Pearson and Spearman correlation coefficients between AADT and the principal explanatory variables, extending the descriptive and disruption analyses by examining the strength and form of their associations with traffic demand. Passenger population density recorded the strongest positive association under both measures (Pearson $r = 0.791$; Spearman $\rho = 0.819$), followed by GDP, while rainfall and pothole volume showed moderate-to-weak positive associations, indicating that socioeconomic and demographic conditions were more strongly associated with AADT than environmental and pavement-condition factors. The differences between Pearson and Spearman coefficients, particularly for GDP, rainfall and pothole volume, suggest that some relationships may be monotonic but not strictly linear, while the weak association with year ($r = 0.141$; $\rho = 0.203$) further supports the earlier finding that the pronounced 2020 traffic disruption cannot be adequately represented by a simple temporal trend alone.

5. DISCUSSION

The first major finding is the pronounced spatial heterogeneity of traffic demand. Enugu–Port Harcourt carried substantially more traffic on average than the other study corridors, while Abakaliki–Ogoja had the lowest mean. This pattern is consistent with the general observation that AADT varies with roadway,

socioeconomic and land-use context and that spatial grouping can improve traffic estimation (Sfyridis & Agnolucci, 2020). In a resilience context, the finding is important because disruption exposure should not be interpreted independently of baseline traffic intensity.

The second major finding is the sharp 2019–2020 reduction. The timing of the decline coincides with the COVID-19 pandemic and movement restrictions in Nigeria. Federal directives in 2020 restricted non-essential interstate passenger travel and imposed other movement controls, while allowing controlled movement of essential goods and services (Federal Ministry of Information and National Orientation, 2020a, 2020b). Nigerian transportation research likewise documented major operational and behavioural changes during the pandemic (Mogaji, 2020; Okeke et al., 2023). The present study therefore interprets 2020 as an observed disruption period rather than assuming that the decline represents an ordinary year-to-year fluctuation.

The third finding is that the disruption was heterogeneous. The proportional reduction ranged from 40.9% to 66.3%. Such differences are consistent with resilience research emphasizing spatial variation in the response of transport systems to disturbances (Bergantino et al., 2024). They may reflect differences in corridor function, economic activity, population catchment, alternative routes, freight dependence and other corridor characteristics. Because these mechanisms were not directly measured here, they should be regarded as plausible explanations rather than demonstrated causal effects.

The fourth finding concerns the interpretation of resilience. A smaller traffic-demand reduction can be viewed as evidence of greater resistance to the observed demand shock, but it is not equivalent to a complete resilience measure. Established resilience frameworks distinguish resistance/robustness from recovery and broader adaptive capacity (Bruneau et al., 2003; Gonçalves & Ribeiro, 2020). The present study therefore uses the term 'traffic-demand retention' to describe the observed response and avoids claiming that one corridor is universally more resilient than another.

The correlation results indicate that demographic and economic context is closely associated with traffic demand. Passenger population density showed the strongest simple association with AADT, while GDP also showed a substantial positive association. These relationships are consistent with transportation-demand reasoning and with AADT studies that incorporate socioeconomic and roadway variables (Sfyridis & Agnolucci, 2020). Nevertheless, the strong correlation among rainfall, pothole volume and other predictors means that environmental coefficients should not be interpreted independently without accounting for multicollinearity.

6. IMPLICATIONS FOR HIGHWAY RESILIENCE AND PLANNING

- Traffic monitoring should preserve long-term corridor-level AADT series because annual averages can reveal structural disruptions that short-duration counts may miss.
- Resilience planning should use corridor-specific disruption benchmarks rather than applying a single regional adjustment factor to all highways, given the observed range of 40.9%–66.3% reductions.

- High-volume corridors should be monitored separately because a given percentage disruption corresponds to very different absolute traffic losses across corridors.
- Emergency traffic-management plans should explicitly consider interstate-movement restrictions, essential freight movement, alternative routes and the potential concentration or diversion of traffic.
- Future resilience assessment should combine traffic-demand indicators with physical condition, network redundancy, travel time, accessibility, freight movement and post-disruption recovery data.
- Continuous or higher-frequency traffic counts would permit monthly or daily analysis of disruption onset and recovery, which cannot be reconstructed reliably from annual observations alone.

7. LIMITATIONS

The dataset contains 100 observations from five corridors and therefore should not be generalized automatically to all Nigerian highways.

The annual temporal resolution prevents precise identification of the onset, duration and within-year dynamics of the 2020 disruption.

The dataset ends in 2020, so post-disruption recovery cannot be measured. The study therefore assesses observed traffic-demand resistance/retention rather than complete resilience.

The 2019–2020 decline coincides with COVID-19 restrictions, but the observational design does not isolate the causal contribution of the pandemic from all other contemporaneous factors.

Corridor characteristics such as freight composition, route diversion, security conditions, land use, capacity constraints and detailed rehabilitation timing were not fully represented in the resilience indicators.

Traffic-demand retention is a single performance dimension and should not be interpreted as a comprehensive resilience score.

8. CONCLUSIONS

This study examined long-term annual traffic-demand patterns and the observed disruption response of five inter-state highway corridors in Southeastern Nigeria using 100 annual corridor observations from 2001–2020. The analysis demonstrated substantial spatial heterogeneity: Enugu–Port Harcourt recorded the highest mean AADT (2,202,095 PCU/day), whereas Abakaliki–Ogoja recorded the lowest (588,709 PCU/day). Regional mean AADT rose from approximately 1.19 million PCU/day in 2001 to 1.64 million PCU/day in 2019 before falling to 808,602 PCU/day in 2020.

The 2019–2020 transition represented a pronounced traffic-demand disruption. The pooled reduction was 50.8%, but the corridor-specific decline ranged from 40.9% to 66.3%, demonstrating that the observed response was not spatially uniform. The associated retention ratios ranged from 33.7% to 59.1%. These measures provide a transparent indication of disruption resistance, but they should not be

interpreted as complete resilience scores because recovery and other resilience dimensions are not available in the dataset.

The study contributes a multicorridor, longitudinal perspective to transportation-resilience research in a data-constrained developing-region context. The results support corridor-specific traffic monitoring, disruption preparedness and resilience planning. Future research should extend the observation period beyond 2020, incorporate higher-frequency traffic data and integrate network redundancy, travel-time reliability, freight activity, pavement condition and recovery indicators to construct a more comprehensive resilience assessment.

Declarations

Consent for publication

Not applicable. This manuscript does not contain individual-level personally identifiable information or other material requiring consent for publication.

Availability of data and materials

The datasets generated and/or analysed during the current study are available from the corresponding author on reasonable request, subject to any restrictions associated with the original data sources.

Competing interests

The authors declare that they have no competing interests.

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Figures

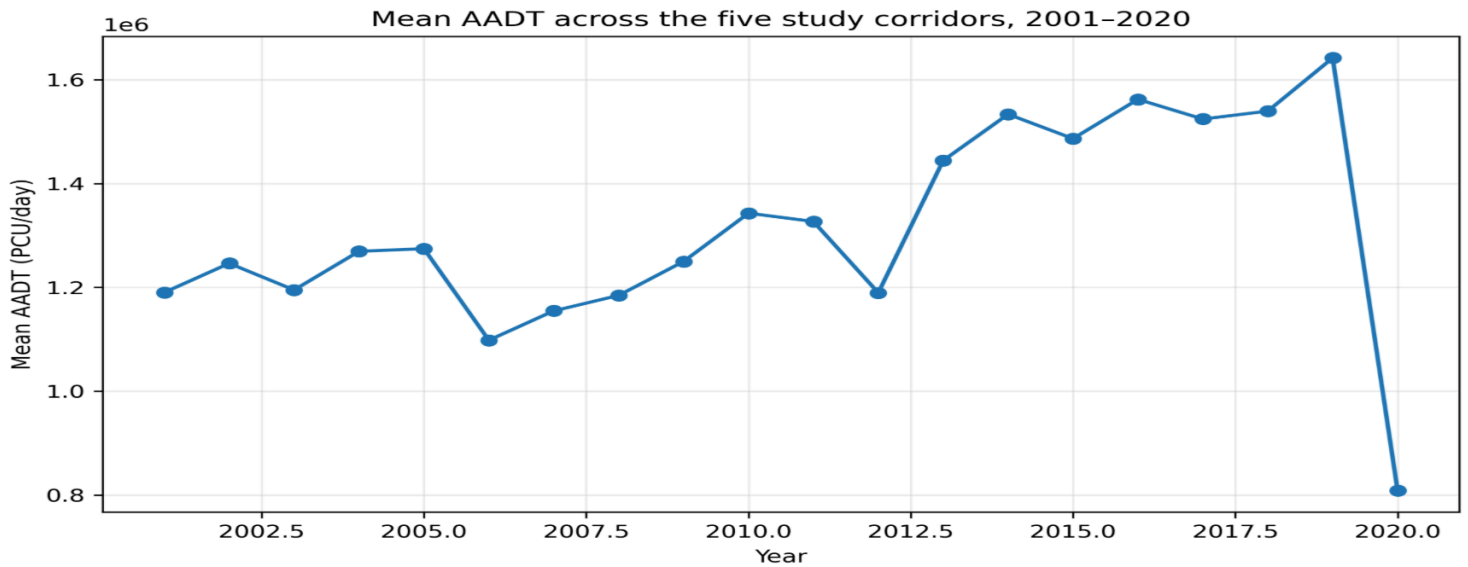


Figure 1

Mean AADT across the five study corridors, 2001–2020

The Enugu–Port Harcourt corridor recorded the highest mean AADT (2,202,095 PCU/day), substantially exceeding the other corridors, while Abakaliki–Ogoja had the lowest mean AADT (588,709 PCU/day). The marked differences in average traffic demand highlight substantial corridor-level heterogeneity, reflecting differences in commercial activity, population concentration, connectivity and the functional importance of the respective inter-state highways.

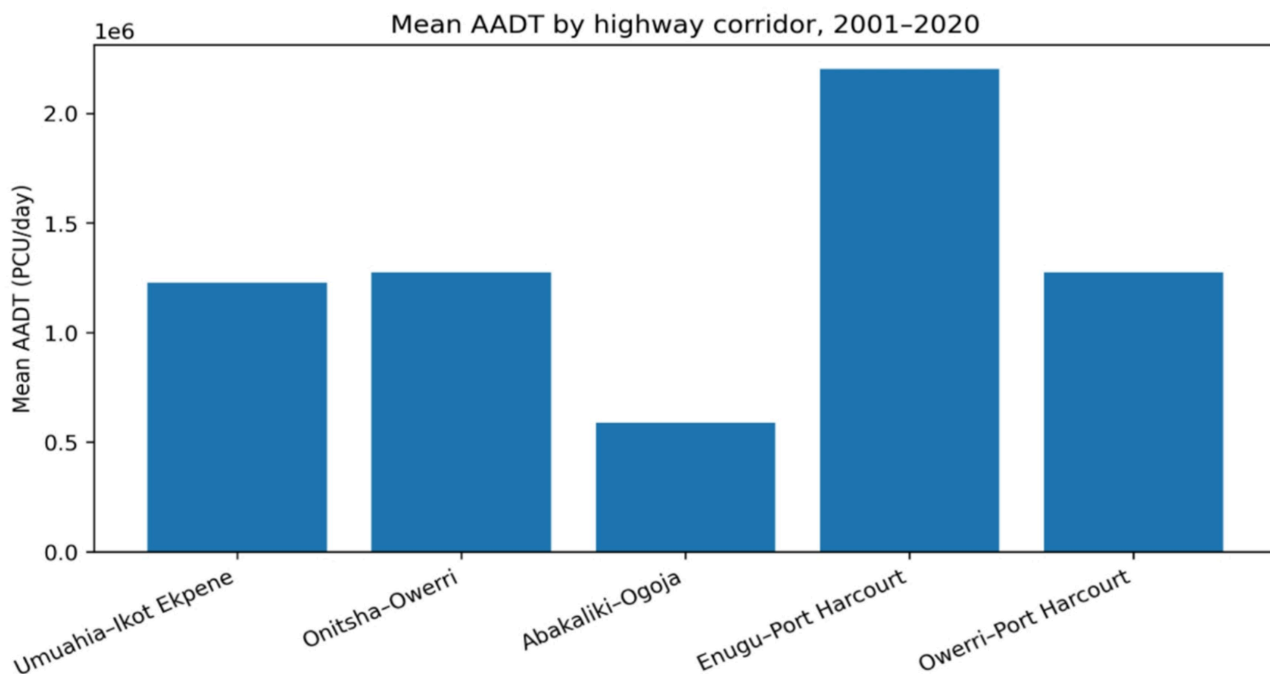


Figure 2

Mean AADT by highway corridor, 2001–2020

The Enugu–Port Harcourt corridor recorded the highest mean AADT (2,202,095 PCU/day), followed by Owerri–Port Harcourt (1,274,232 PCU/day), Onitsha–Owerri (1,273,647 PCU/day), and Umuahia–Ikot Ekpene (1,226,869 PCU/day), while Abakaliki–Ogoja recorded the lowest mean value (588,709 PCU/day). The substantial differences in mean traffic demand indicate pronounced corridor-level heterogeneity, which may reflect variations in economic activity, population concentration, connectivity, and the strategic functional roles of the respective highways.

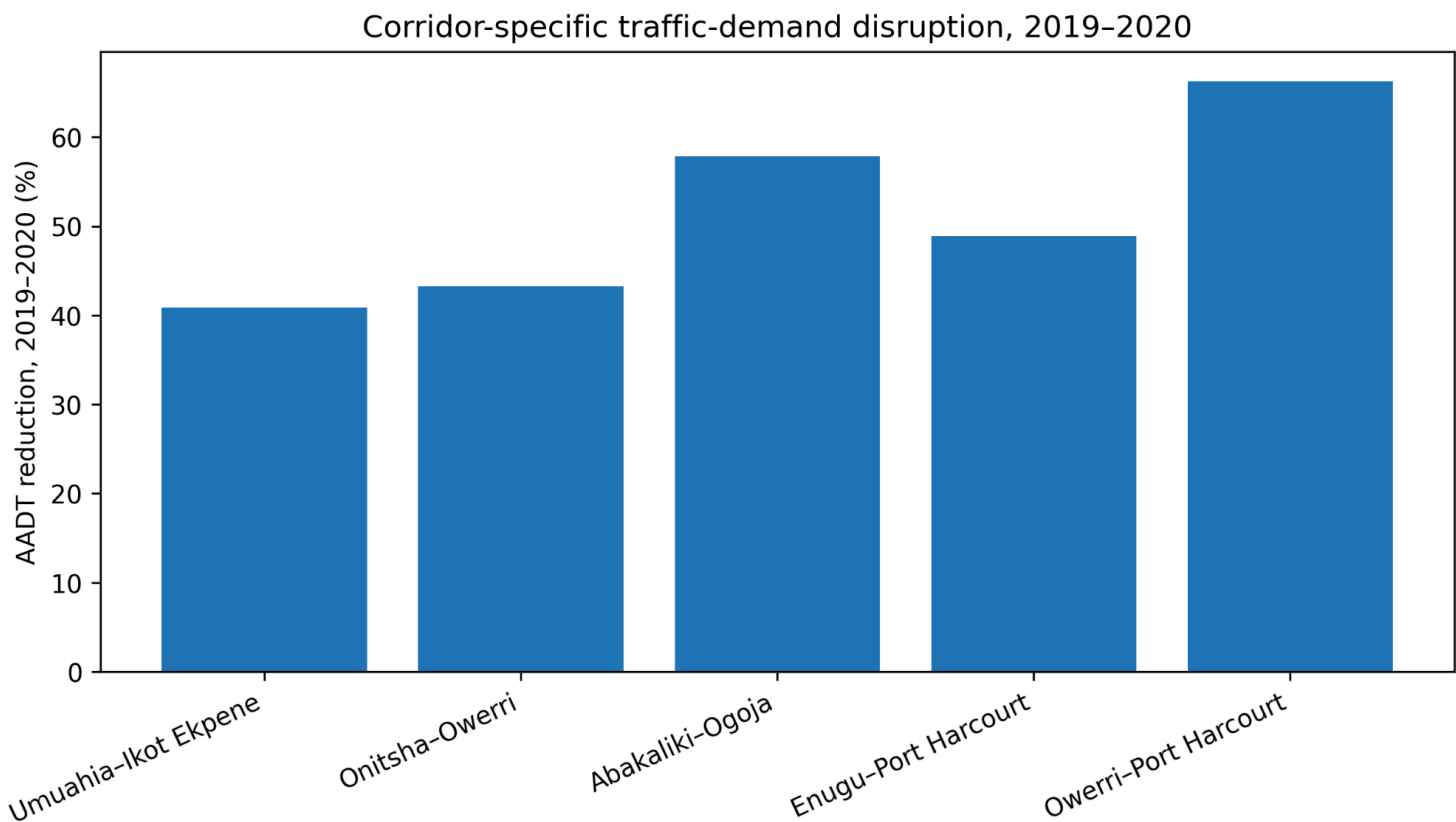


Figure 3

Corridor-specific traffic-demand disruption between 2019 and 2020

illustrates the magnitude and corridor-specific pattern of traffic-demand disruption between 2019 and 2020, providing evidence of a pronounced contraction in inter-state highway activity across the study area. Mean AADT declined on all five corridors, with the largest reduction occurring on Owerri–Port Harcourt (66.3%), followed by Abakaliki–Ogoja (57.8%), Enugu–Port Harcourt (48.9%), Onitsha–Owerri (43.3%), and Umuahia–Ikot Ekpene (40.9%), indicating that the disruption was widespread but varied substantially in intensity across corridors. This heterogeneous response suggests that the 2020 traffic shock did not affect highway demand uniformly, but was conditioned by differences in corridor function,

commercial dependence, mobility intensity and network connectivity, with the sharper declines pointing to greater sensitivity of some routes to mobility restrictions and disruptions in economic activity.

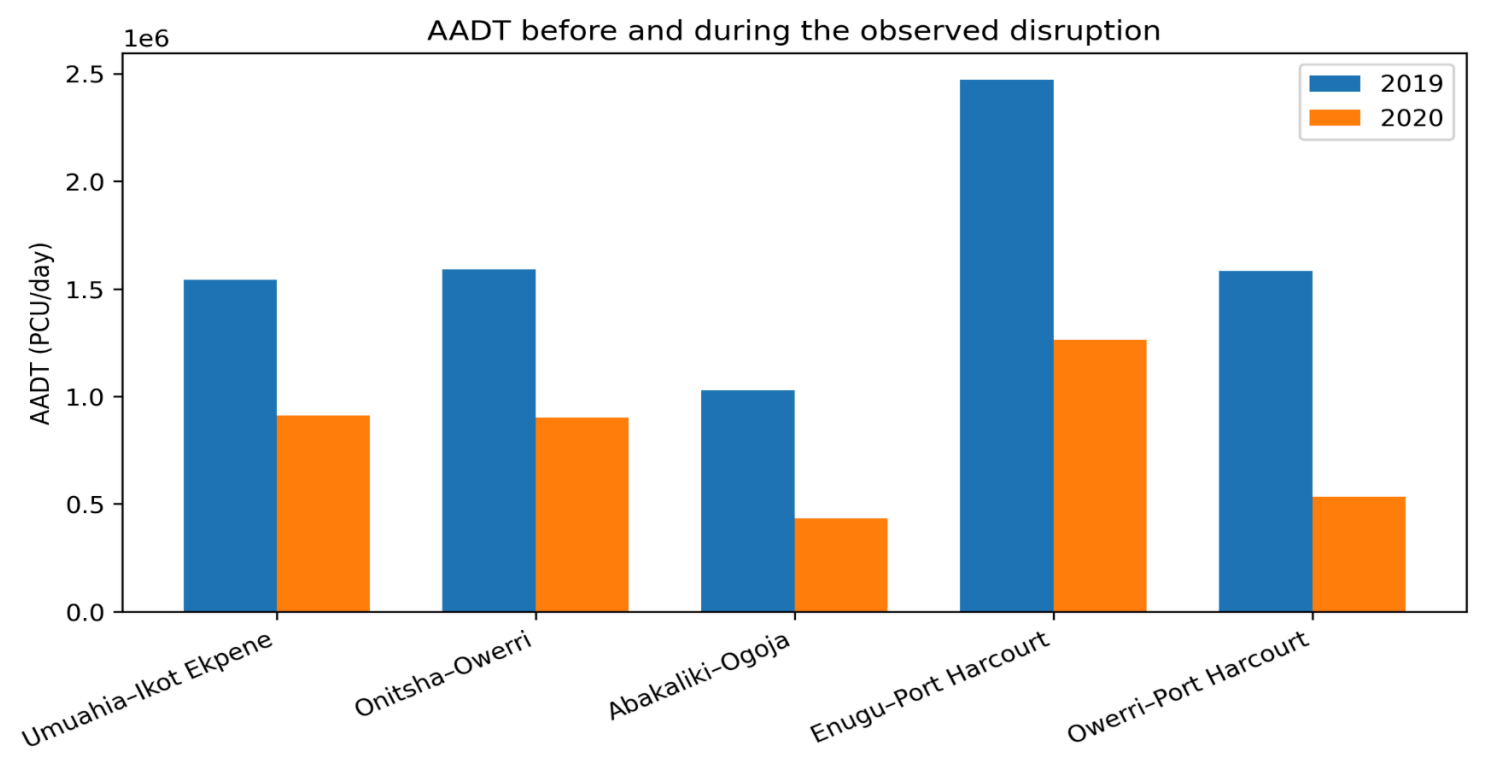


Figure 4

AADT before and during the observed disruption

The figure shows a marked contraction in traffic demand during 2020 following the relatively higher AADT levels recorded in the preceding years, consistent with the substantial corridor-level reductions of 40.9% to 66.3% reported in the earlier results. The sharp decline provides further evidence of a widespread but heterogeneous traffic-demand shock, demonstrating that the observed disruption represented a substantial departure from the prevailing traffic pattern rather than a continuation of the long-term AADT trend.