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Research Article

# Determination of Follow-Up Headway of Local Drivers at Urban Multilane Roundabouts in Gombe Metropolis

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**Articles History: Received:** 30 June 2026; **Revised:** 31 August 2026; **Accepted:** 8 September 2026; **Published:** 11 September 2026



## Abstract

Accurate estimation of follow-up headway is fundamental for the operational analysis of urban roundabouts, especially in regions with heterogeneous traffic. This study presents a field-based approach to determining follow-up headway at three typical multilane roundabouts in Gombe metropolis, Nigeria, utilizing unmanned aerial vehicle (UAV) video surveys and rigorous manual data extraction. The 50th percentile method was applied to determine operational headway values for each roundabout. The results indicate a mean follow-up headway of 2.01 seconds, with site-specific values of 2.02 seconds (Central Roundabout), 2.20 seconds (Dukku Park Roundabout), and 1.80 seconds (Union Bank Roundabout), reflecting the combined influence of local geometry, driver behavior, and traffic composition. Variability between the sites highlights the importance of local context, as geometric complexity and the traffic characteristics affect headway selection. These findings reinforce the limitations of adopting foreign default values for capacity analysis in Nigerian settings. The study recommends adopting locally measured parameters in the capacity analysis of roundabouts with simulation and analytical tools such as the Highway Capacity Manual Models. The empirical results provide evidence-based direction for roundabout design and policy in rapidly urbanizing African cities.

**Keywords:** Headway, Urban, Roundabout, Heterogeneous, Traffic, Multilane

## Introduction

Roundabouts are circular intersections featuring one-way traffic around a central island and yield control at entries, designed to increase intersection safety and operational efficiency [1,2]. Their growing adoption worldwide has been attributed to reduced crash severity, lower vehicle speeds, and fewer conflict points compared to traditional intersections [3,4]. In developing countries like Nigeria, multilane roundabouts have become integral to urban traffic management, particularly as cities expand and auto-mobile rates soar [5,6].

At the core of roundabout performance is the concept of gap acceptance, which influences how drivers decide to enter the circulating flow. Two key metrics guide this process; the critical gap and the follow-up headway (the interval between consecutive vehicles entering via an accepted gap). These parameters are foundational to international capacity estimation methods, notably the Highway Capacity Manual HCM6 [7] and HCM7 [8], which employs standardized equations often adopted in design and operational analysis [9].

Despite proven efficacy in homogeneous traffic environments, evidence reveals substantial regional variation in driver behavior, traffic mix, and adherence to priority rules, making direct application of HCM default parameters unreliable in developing countries [3,9]. Recent studies emphasize that heterogeneous traffic is characterized by mixed vehicle types, such as motorcycles, tricycles, cars, and trucks, which affects critical traffic parameters and merging behaviors [2,3]. For instance, Ahmed et al. [3] found that motorcyclists often accept shorter gaps than other drivers, thus significantly impacting capacity and safety outcomes. In Nigeria, field-based investigations into gap acceptance parameters at urban roundabouts, especially regarding follow-up headway, remain scarce [5]. Current evaluations mostly depend on simulation tools like SIDRA and ARCADY, often using foreign default settings [5]. Such practice can lead to misaligned capacity estimations and suboptimal infrastructure solutions[10-12]. Moreover, the application of contemporary data collection methods such as UAV (drone) video analysis, a standard in recent studies [1,3].

This study seeks to empirically determine the follow-up headway of local drivers at urban multilane roundabouts in Gombe metropolis, Nigeria, using UAV-based traffic data and percentile estimation approaches. This study is justified by the urgent need to bridge knowledge gaps, improve practical capacity estimations, and promote safer, more sustainable roundabout design tailored to Nigerian local realities [1-3].

By implementing recent international data collection and analysis techniques for the first time in Gombe, this study provides empirical evidence crucial for calibrating capacity models in Nigerian cities. The findings will empower local agencies to optimize roundabout design and management while contributing to the global understanding of driver behavior in heterogeneous traffic contexts [1,3,4]

## Materials and Methods

### Study Locations

To obtain representative and generalizable findings, a study was conducted on three four-legged urban multilane roundabouts within the Gombe metropolis: Central, Union Bank, and Tashan Dukku (Dukku Park) roundabouts. Figures 1a through 1d display the Google images of these roundabouts.

The selected sites are strategically located and characterized by high traffic volumes, geometric diversity, and their significance as key nodes in the city’s road network. This selection process follows best practices in traffic engineering research, ensuring the inclusion of locations with typical and varied operational conditions to effectively capture the range of local driving behaviors and traffic compositions.


(a)


(b)


(c)


(d)

**Figure 1.** Study Locations of Roundabouts in Gombe: (a) Spatial Position of the Representative Roundabouts; (b) Dukku Park; (c) Central; (d) Union Bank

### *Data Collection*

A comprehensive data collection process was undertaken to obtain and document traffic activities at the three roundabouts. This procedure involved the utilization of Unmanned Aerial Vehicles (UAVs or drones), positioned approximately 12 meters above each roundabout. The UAVs provided a complete aerial perspective, enabling observation of all roundabout approaches and ensuring minimal disruption to traffic flow. Observations and Video recordings were conducted during weekday peak hours of morning and evening from Tuesday to Wednesday in the month of February 2023 at each location.

UAVs offer significant advantages in traffic studies, providing robust and objective video records for later analysis. Their deployment is increasingly viewed as a state-of-the-art tool in collecting accurate and efficient data, particularly in roundabout headway studies internationally, as noted by Ahmed et al. [3] and Chun et al. [1].

To enhance the analysis, Time Add-On Software was employed to incorporate timestamping at the millisecond level on each video, facilitating precise measurement of vehicle passage times. VLC Player software was used for flexible video playback, allowing for the manual extraction of headway data. Data from each roundabout approach were analyzed independently, and timestamps were recorded into Excel. Key geometric characteristics of the roundabouts used for data collection is summarized in Table 1.

### *Headway Data Extraction and Analysis Method*

The manual method of data extraction was performed by reviewing each roundabout approach separately, recording vehicle timestamps at the conflict zone (i.e., merging area). The 50th percentile method was used to estimate the follow-up headway, in line with international practice and previous studies in developing country settings [13,14]. This method is preferred for its simplicity and resilience to extreme outliers; it calculates the median interval between successive vehicles that utilize a common gap in the circulating traffic. Data from each roundabout were analyzed in Excel spreadsheets, cumulative percentages were computed, and graphical analysis was conducted to identify the 50th percentile value as the representative local follow-up headway.

**Table 1.** Geometric Properties of the Studied Roundabouts

| S/N | Roundabout | Coordinates | Type | CID (m) | Wa (m) | Wc (m) |
|---|---|---|---|---|---|---|
| 1. | Central Roundabout | $10^0$17″13.57′N, $11^0$9″58.52′E | Multilane | 34.88 | 9.30 | 15.76 |
| 2. | Union Bank Roundabout | $10^0$16″48.64′N, $11^0$10″49.83′E | Multilane | 27.87 | 9.85 | 14.96 |
| 3. | Dukku Park Roundabout | $10^0$18″1.59′N, $11^0$9″41.86′E | Multilane | 49.58 | 12.08 | 15.00 |

## Results and Discussion

The results of this study aimed at determining the follow-up behavior of local drivers at roundabouts in Gombe metropolis, in Gombe State of Nigeria are presented and discussed as follows:

### Follow-up Headway Results for Central Roundabout

The follow-up headway at Central Roundabout was established at 2.02 seconds using the 50th percentile method (Table 2 and Figure 2). This value is close to the mean follow-up headway (2.01 s) computed across all sites. The close correspondence arises because Central Roundabout, by virtue of its geometric attributes (CID: 34.88 m, Wa: 9.30 m, Wc: 15.76 m) represents a typical urban multilane roundabout in Gombe, combining moderate approach widths, a balance of vehicle flows, and representative driver behavior. Its central location in the metropolis may expose it to a more diverse set of drivers, but its operation reinforces 'average' conditions for the city. As supported by a recent study by Hassan et al. [2], roundabouts with moderate geometry and mixed, but not extreme, traffic streams often reflect citywide means for operational parameters. The follow-up headway value at the Central Roundabout is indicative of expected queue discharge rates and driver patience for Gombe-type environments. In addition, It also demonstrates that using city average for follow-up headway in the absence of site-specific data is justifiable [1,2].

### Follow-up Headway Results for Tashan Dukku (Dukku Park) Roundabaout

Dukku Park Roundabout exhibited the highest follow-up headway at 2.20 seconds (Table 3 and Figure 3). This higher value of headway can be attributed to the largest central island diameter (CID: 49.58 m) and approach width (Wa: 12.08 m) among the three, which may create longer judgment zones and a sense of scale that encourages more conservative gap acceptance. Also, its position may serve as a terminal or interface for longer journeys, including freight trips, raising the proportion of cautious heavy vehicle maneuvers.

A higher follow-up headway denotes more cautious (slower) entry, which, as found by Ahmed et al. [3], is typical at sites with wider circulatory lanes and more varied traffic mixes. Geometric complexity and less familiar traffic streams often prompt drivers to seek safer, larger gaps as reflected here. Similar findings have been observed in large diameter roundabouts internationally [15].

**Table 2.** Calculation Process of Follow-Up Headway Using 50th Percentile (Central Roundabout)

| Headway | Class Boundary | Frequency | Cumulative | Cumulative Percentage |
|---|---|---|---|---|
| 0.0 - 0.5 | 0.50 | 48.00 | 48.00 | 1.34 |
| 0.5 - 1.0 | 1.00 | 328.00 | 376.00 | 10.48 |
| 1.0 - 1.5 | 1.50 | 783.00 | 1159.00 | 32.31 |
| 1.5 -2.0 | 2.00 | 590.00 | 1749.00 | 48.75 |
| 2.0 - 2.5 | 2.50 | 382.00 | 2131.50 | 59.41 |
| 2.5 - 3.0 | 3.00 | 260.00 | 2391.50 | 66.66 |
| 3.0 - 3.5 | 3.50 | 252.00 | 2643.50 | 73.69 |
| 3.5 - 4.0 | 4.00 | 128.00 | 2771.50 | 77.25 |
| 4.0 - 4.5 | 4.50 | 144.00 | 2915.50 | 81.27 |
| 4.5 - 5.0 | 5.00 | 112.00 | 3027.50 | 84.39 |
| 5.0 - 5.5 | 5.50 | 112.00 | 3139.50 | 87.51 |
| 5.5 - 6.0 | 6.00 | 100.00 | 3239.50 | 90.30 |
| 6.0 - 6.5 | 6.50 | 92.00 | 3331.50 | 92.86 |
| 6.5 - 7.0 | 7.00 | 60.00 | 3391.50 | 94.54 |
| 7.0 - 7.5 | 7.50 | 64.00 | 3455.50 | 96.32 |
| 7.5 - 8.0 | 8.00 | 44.00 | 3499.50 | 97.55 |
| 8.0 - 8.5 | 8.50 | 32.00 | 3531.50 | 98.44 |
| 8.5 - 9.0 | 9.00 | 20.00 | 3551.50 | 99.00 |
| 9.0 - 9.5 | 9.50 | 20.00 | 3571.50 | 99.55 |
| 9.5 - 10.0 | 10.00 | 16.00 | 3587.50 | 100.00 |
| | | 3587.00 | | |

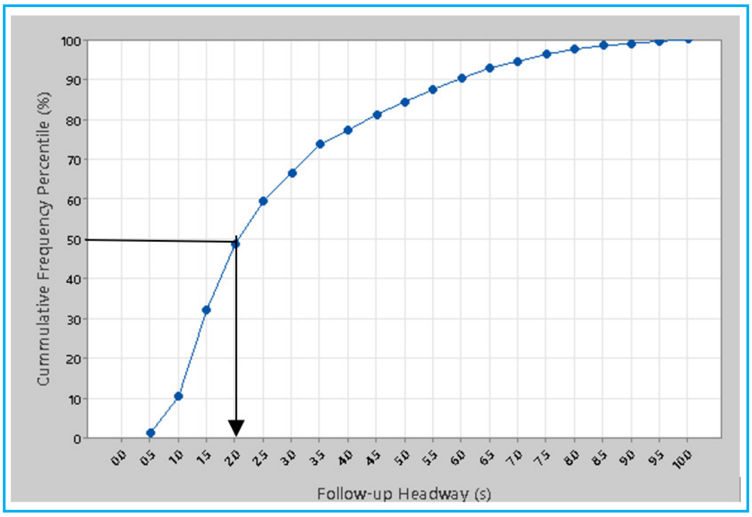


**Figure 2.** Follow-up headway for Central Roundabout Gombe, Gombe State

### *Follow-up Headway Results for Union Bank Roundabout*

Among the three roundabouts studied, Union Bank Roundabout was found to have the lowest follow-up headway value of 1.80 seconds, the results are presented in Table 4 and Figure 4.

This value suggests more aggressive entry, likely due to; a smaller circulatory diameter (CID: 27.87 m) and approach width (Wa: 9.85 m), making the roundabout easier to scan and gaps appear more accessible. Also, a high prevalence of motorcycles and tricycles, whose drivers accept smaller gaps, is consistent with previous findings in mixed-traffic environments [3].

**Table 3.** Cumulative Frequency Table of Headway Distribution at Dukku Park Roundabout

| Headway Distribution | Class Boundary | Frequency | Cumulative | Cumulative Percentage |
|---|---|---|---|---|
| 0.0 - 0.5 | 0.50 | 96.00 | 96.00 | 3.58 |
| 0.5 - 1.0 | 1.00 | 424.00 | 520.00 | 19.40 |
| 1.0 - 1.5 | 1.50 | 376.00 | 896.00 | 33.43 |
| 1.5 -2.0 | 2.00 | 340.00 | 1236.00 | 46.12 |
| 2.0 - 2.5 | 2.50 | 295.00 | 1531.00 | 57.13 |
| 2.5 - 3.0 | 3.00 | 264.00 | 1795.00 | 66.98 |
| 3.0 - 3.5 | 3.50 | 198.00 | 1993.00 | 74.37 |
| 3.5 - 4.0 | 4.00 | 105.00 | 2098.00 | 78.28 |
| 4.0 - 4.5 | 4.50 | 114.00 | 2212.00 | 82.54 |
| 4.5 - 5.0 | 5.00 | 60.00 | 2272.00 | 84.78 |
| 5.0 - 5.5 | 5.50 | 56.00 | 2328.00 | 86.87 |
| 5.5 - 6.0 | 6.00 | 64.00 | 2392.00 | 89.25 |
| 6.0 - 6.5 | 6.50 | 52.00 | 2444.00 | 91.19 |
| 6.5 - 7.0 | 7.00 | 36.00 | 2480.00 | 92.54 |
| 7.0 - 7.5 | 7.50 | 48.00 | 2528.00 | 94.33 |
| 7.5 - 8.0 | 8.00 | 44.00 | 2572.00 | 95.97 |
| 8.0 - 8.5 | 8.50 | 20.00 | 2592.00 | 96.72 |
| 8.5 - 9.0 | 9.00 | 36.00 | 2628.00 | 98.06 |
| 9.0 - 9.5 | 9.50 | 20.00 | 2648.00 | 98.81 |
| 9.5 - 10.0 | 10.00 | 32.00 | 2680.00 | 100.00 |
| | | 2680.00 | | |

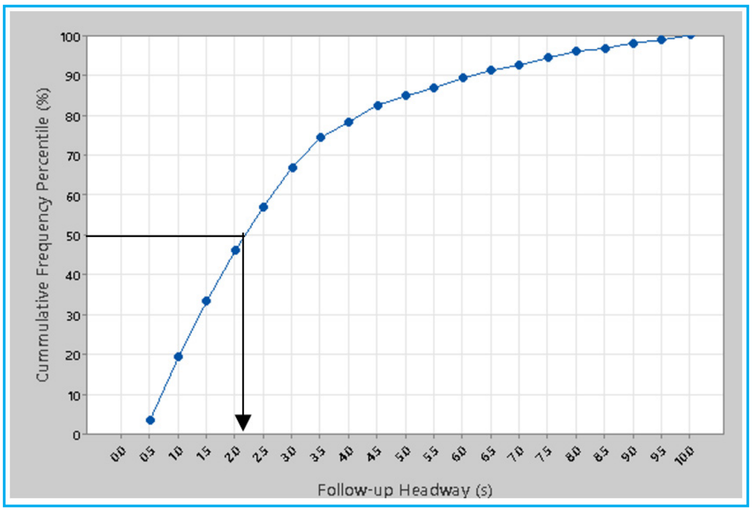


**Figure 3.** Follow up headway for Tashan Dukku (Dukku Park) Roundabout Gombe, Gombe State

Additionally, low values of follow-up headway increase flow but may compromise safety if aggressive maneuvers predominate. Literature emphasizes these behaviors in contexts where traffic is dominated by smaller, more maneuverable vehicles with variable compliance [3].

https://doi.org/10.70028/dcea.v3i2.121

**Table 4.** Cumulative Frequency Table of Headway Distribution at Union Bank Roundabout

| Headway Distribution | Class Boundary | Frequency | Cumulative | Cumulative Percentage |
|---|---|---|---|---|
| 0.0 - 0.5 | 0.50 | 56.00 | 56.00 | 1.78 |
| 0.5 - 1.0 | 1.00 | 436.00 | 492.00 | 15.65 |
| 1.0 - 1.5 | 1.50 | 732.00 | 1224.00 | 38.93 |
| 1.5 -2.0 | 2.00 | 428.00 | 1652.00 | 52.54 |
| 2.0 - 2.5 | 2.50 | 316.00 | 1968.00 | 62.60 |
| 2.5 - 3.0 | 3.00 | 244.00 | 2212.00 | 70.36 |
| 3.0 - 3.5 | 3.50 | 160.00 | 2372.00 | 75.45 |
| 3.5 - 4.0 | 4.00 | 108.00 | 2480.00 | 78.88 |
| 4.0 - 4.5 | 4.50 | 96.00 | 2576.00 | 81.93 |
| 4.5 - 5.0 | 5.00 | 92.00 | 2668.00 | 84.86 |
| 5.0 - 5.5 | 5.50 | 84.00 | 2752.00 | 87.53 |
| 5.5 - 6.0 | 6.00 | 104.00 | 2856.00 | 90.84 |
| 6.0 - 6.5 | 6.50 | 76.00 | 2932.00 | 93.26 |
| 6.5 - 7.0 | 7.00 | 32.00 | 2964.00 | 94.27 |
| 7.0 - 7.5 | 7.50 | 36.00 | 3000.00 | 95.42 |
| 7.5 - 8.0 | 8.00 | 40.00 | 3040.00 | 96.69 |
| 8.0 - 8.5 | 8.50 | 24.00 | 3064.00 | 97.46 |
| 8.5 - 9.0 | 9.00 | 24.00 | 3088.00 | 98.22 |
| 9.0 - 9.5 | 9.50 | 28.00 | 3116.00 | 99.11 |
| 9.5 - 10.0 | 10.00 | 28.00 | 3144.00 | 100.00 |
| | | 3144.00 | | |

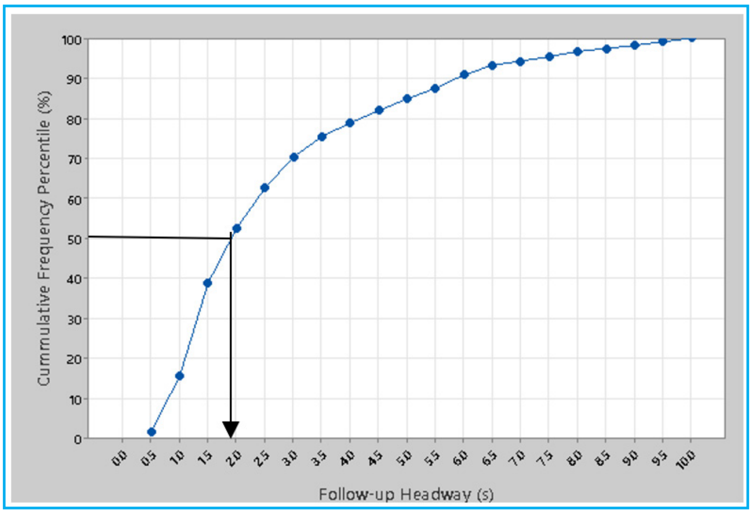


**Figure 4.** Follow up headway for Union Bank Roundabout Gombe, Gombe State

### *Comparison of the Follow-up Headway at Roundabouts in Gombe*

Figure 5 shows the comparison of the headway distribution among the three sites; all three sites show a similar trend despite the difference in their median. The overall variability in follow-up headway across the three representative roundabouts ranged from 1.80 to 2.20 s, which is consistent with empirical evidence that local geometric configuration, traffic composition, and traffic mix are major determinants of gap acceptance [2,3,13].

The mean follow-up headway of 2.01 seconds represents a realistic operational parameter for Gombe metropolis and is directly supported by the balanced central site value (Central Roundabout, 2.02 s), the city's network average configuration.

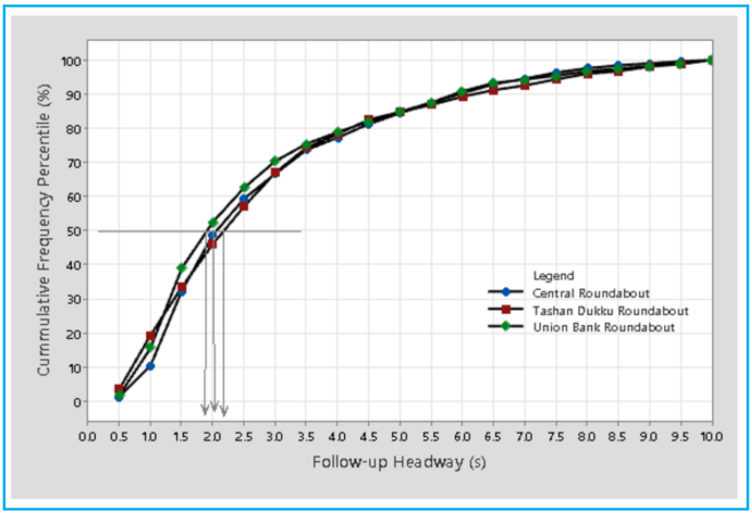


**Figure 5.** Comparison of Follow-up Headway Distributions for the Roundabouts in Gombe Metropolis

## CONCLUSION

This study empirically established the follow-up headway of local drivers at three multilane roundabouts in Gombe metropolis using UAV-based video analysis. The findings reveal a mean follow-up headway of 2.01 seconds, with variability across sites attributable to differences in geometry, and traffic composition. This value is lower than standards usually assumed in international manuals, most importantly the highway capacity manual, HCM 6, (where the cited default value for the overall weighted average across all multi-lane configurations studied to build the HCM 6 model is 2.54 seconds), hence highlighting the need for local calibration. The results provide a local parameter for capacity analysis and design of urban roundabouts in Gombe and similar Nigerian conditions.

In line with the study findings, the study recommends:

1. Transportation planners and engineers should use the locally derived mean follow-up headway of 2.01 seconds for roundabout design, performance analysis, and capacity estimation in Gombe and comparable cities.
2. Authorities should implement targeted educational outreach and stricter enforcement—especially for motorcycle and tricycle drivers—on safe gap acceptance and roundabout negotiation.
3. Further studies should extend UAV-based data collection and headway analysis to other Nigerian cities and varied roundabout forms to develop more comprehensive regional standards.
4. Urban and regional transport policies should mandatorily require locally validated operational parameters for all major intersection designs.
5. Periodic review involving regular updating of operational traffic parameters to reflect evolving road user composition and behaviors due to rapid urbanization and motorization in developing countries.

On the easting that construction projects involve high levels of risk encompassing health, safety, and environmental aspects; thus, an integrated risk management approach is required to identify and control various sources of hazards.

## Acknowledgement

The authors gratefully acknowledge the support of the Department of Civil Engineering, Abubakar Tafawa Balewa University Bauchi, and the Department of Civil Engineering, Bayero University Kano. Special thanks to field assistants and colleagues who contributed to data collection and preliminary analyses. The constructive feedback from peer reviewers is also highly appreciated.

## Conflicts of Interest

The authors declare no conflict of interest.

## Author Contributions

**Abubakar Usman Baraya:** conceptualization, methodology, data curation, formal analysis, writing-original draft. **Ahmad Batari:** conceptualization, supervision, methodology, data curation, writing-review & editing. **Muttaqa Na'iya Ibrahim:** conceptualization, supervision, writing-review & editing.

## Data Availability Statement

The datasets generated and/or analysed during the current study are available from the corresponding author on reasonable request.

## Declaration of Generative Ai and Ai-Assisted Technologies in the Writing Process

Not Applicable.

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