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Safe Mobility for Women and the Spatial Availability of Public Transport in Moradabad: A Geographical Study

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Abstract
The presence of a public transport route does not, by itself, mean that people can use it easily or safely. This study examines the four Moradabad e-city-bus routes reported in January 2022 and considers them alongside Census 2011 data, the 2023 Moradabad Smart City project inventory, and a 2024 report on bus shelters. Using these secondary sources, the study establishes a reproducible baseline for examining the structure of the city's documented bus network. A 4 × 33 route–stop incidence matrix was analysed through descriptive statistics, stop-frequency counts, the Gini coefficient, and pairwise Jaccard similarity. The four routes contained 66 route–stop calls and covered 33 distinct named stops. Route lengths were similar, averaging 16.5 stops (CV = 3.50%). Of the 33 unique stops, 84.8% appeared on at least two routes. The distribution of route frequency across stops was relatively even (Gini = 0.129), although overlap between individual route pairs varied considerably (J = 0.100–0.435). This pattern suggests that services share particular corridors rather than forming a uniformly integrated network. Smart City records also document 20 high-mast lighting installations, 34 public bicycle/e-bike stations with 300 bicycles, and round-the-clock monitoring through the Intelligent Command and Control Centre (ICCC). These facilities may support safer journeys, but the available records cannot establish whether women feel safer or whether their travel has changed. A reliable assessment of walking access, journey times, and women's safety will require geocoded transport data and evidence disaggregated by gender.

Keywords: *women's mobility; public transport; transport accessibility; gender and transport; urban geography; Moradabad; route-network analysis*

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I. Introduction

A bus stop's existence is only one part of a usable public transport system. Women's ability to travel also depends on how easily they can reach the stop, the conditions in which they wait, the reliability of the service, and the safety of the first and last parts of the journey. Lighting, visibility, social inclusion, and the risk of harassment can influence whether a journey feels possible in practice. These concerns are connected to fares, time of day, the quality of public spaces, and wider gender norms (Jain & Campbell, 2022; Roy & Bailey, 2021; Valan, 2020).

Moradabad provides a useful case for examining these issues in a medium-sized city. According to the 2011 Census, the Moradabad Municipal Corporation had a population of 887,871, including 423,291 women .The reported sex ratio was about 911 women per 1,000 men. These figures are used as a demographic reference because they are the most relevant census data available for this study; they should not be treated as a current population estimate. Since then, the city has introduced electric city buses and developed additional Smart City mobility infrastructure.

This study maps the documented structure of Moradabad's e-bus routes, identifies where routes share stops, and reviews how transport services relate to infrastructure that may support safer journeys. It distinguishes three related ideas. **Availability** means that a service or facility exists; **accessibility** concerns how readily people can reach and use it; and **safe mobility** includes both actual and perceived safety throughout a journey. Because a validated geocoded stop-to-ward dataset and local evidence on women's

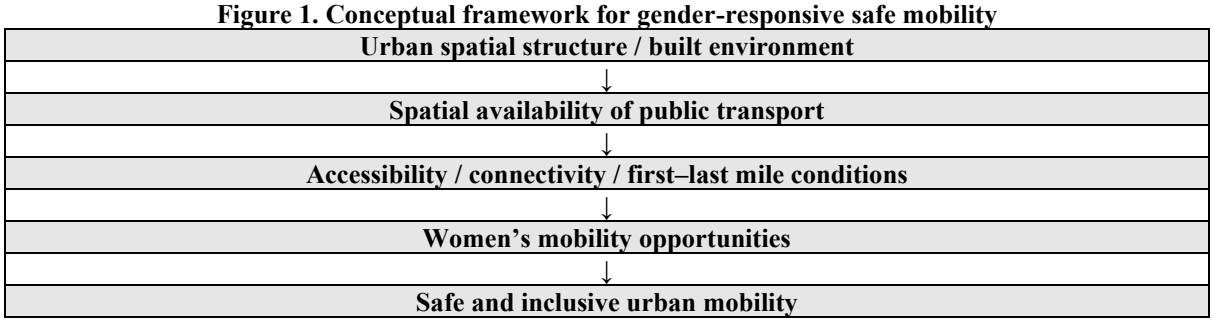
safety perceptions were not available, the study does not claim to measure walking access or safety outcomes. Instead, it establishes a baseline that can inform a later GIS-based, gender-responsive accessibility audit.

Table 1. Research objectives, questions and analytical basis

ID	Objective	Research question	Analytical basis
O1 / RQ1	Analyse the documented distribution and redundancy of e-bus stops.	How concentrated is route availability across the four documented routes?	Complete-network route–stop incidence and frequency measures.
O2 / RQ2	Identify stronger and weaker inter-route corridor overlap.	Which route pairs show the greatest/least topological overlap?	Pairwise Jaccard similarity.
O3 / RQ3	Relate transport provision to women-relevant support infrastructure.	What structural safety/first-last-mile measures are documented?	Triangulation with 2023 Smart City and 2024 shelter records.
O4 / RQ4	Define evidence needed for a defensible gender-responsive spatial audit.	What cannot be inferred from the present data?	Explicit separation of availability, accessibility and safe mobility.

Note. No inferential null hypothesis was tested. The route lists describe the complete set of four documented routes considered in this study, rather than a probability sample.

Figure 1. Conceptual framework for gender-responsive safe mobility



Contextual factors include land use, the distribution of the female population, service availability, lighting and surveillance, public-space conditions, and socio-spatial inequality.

II. Review of Literature and Research Gap

Recent research increasingly treats gender and mobility as connected to the transport system as a whole, rather than to the vehicle alone. Multi-city evidence has identified gender differences in how safe people feel when using public transport (Ait Bihi Ouali et al., 2020), while research on waiting and transfer times shows that the experience of a journey can affect women's sense of security even when a service is available (Chowdhury & van Wee, 2020). Studies in India have documented how sexual harassment can undermine the usefulness of public transport (Valan, 2020), how women's use of buses in Delhi varies by time of day (Jain & Campbell, 2022), and how women in Kolkata negotiate, defend, or avoid particular public spaces (Roy & Bailey, 2021). Together, these findings support a broader approach to transport planning—one that considers the full journey, access, and personal control, rather than relying only on service counts (Joshi et al., 2022; Joshi & Bailey, 2023; Noor & Iamtrakul, 2023). Research on post-COVID mobility in South Asia also links transport barriers with unequal livelihood opportunities (Shah et al., 2023).

Accessibility studies offer complementary ways to understand who can reach transport and the opportunities it connects them to. Research in Lucknow and Mumbai highlights the value of considering stop proximity alongside network connections, population distribution, and land-use patterns (Adhvaryu & Kumar, 2021; Sharma & Patil, 2021). Studies in other settings likewise show that accessibility depends on more than distance: the complexity of a journey and differences between population groups also matter (Da Silva et al., 2022; Giannotti et al., 2022; Salih & Lee, 2022). Measuring access with simple walking-distance buffers alone can overlook barriers and contribute to exclusion (Ribeiro et al., 2021). GIS-based comparisons and analyses of active and passive accessibility can therefore answer different planning questions (Biswas et al., 2023; Lee & Salih, 2024). Research on older adults further demonstrates why accessibility measures need to reflect the needs and circumstances of the people being studied (Ravensbergen et al., 2022).

Safety and service quality are closely related, but they should not be treated as interchangeable measures. Passenger-satisfaction research reports gender differences in perceptions of connectivity, comfort, and station facilities (Singh & Kathuria, 2023). A systematic review published in 2025 identifies safety, security, reliability, and accessibility as important influences on bus use in developing countries (Sogbe et al., 2025). Work with transport providers also argues that women's safety requires a coordinated response, rather than reliance on a single intervention or checklist (Forsdike et al., 2024; Ison & Matthewson, 2023). Smart mobility technology, by itself, does not guarantee gender-responsive outcomes (Uteng, 2021). The gap addressed here is both empirical and geographical: publicly available, gender-disaggregated spatial data remain limited for medium-sized Indian cities such as Moradabad. By analysing the documented bus routes alongside reported Smart City infrastructure, this study offers a baseline review of route-network structure, while recognising that it cannot replace a full spatial accessibility or safety assessment.

III. Data and Methodology

This study uses a quantitative geographical approach based on secondary data; no primary data were collected. The main transport source is a report published on 4 January 2022 describing four Moradabad e-city-bus routes serving central parts of the city and the Pakbara and Bhatavali corridors. For demographic context, the study uses the Moradabad Municipal Corporation figures in the Census of India 2011 Primary Census Abstract. The census geography and the functional area covered by the bus routes are not assumed to be identical. Census figures are therefore presented as context and are not allocated to individual routes or stops.

Four groups of documentary sources were reviewed. The January 2022 route report provided the sequence of stops for each route. Moradabad Smart City Limited's 2023 project presentation documented 14 charging points arranged as two simultaneous bus-charging nodes at each of seven stations, 34 public bicycle/e-bike stations with 300 bicycles, 20 solar high-mast lights, an Intelligent Command and Control Centre (ICCC) with 24-hour monitoring and intelligent traffic management, and 35 public Wi-Fi locations. A September 2024 news report identified 12 existing e-bus shelter locations and stated that 35 modern shelters were under construction. Census 2011 supplied the sex-disaggregated municipal population figures.

Stop names were standardised for spelling and entered into a binary route–stop incidence matrix with four route rows and 33 unique stop columns. A cell was coded 1 when a route served the named stop and 0 otherwise. For each stop, route frequency was calculated by summing the routes that served it. Network redundancy was calculated as the number of route–stop calls divided by the number of unique stops. The Gini coefficient was used to describe inequality in route frequency across stops. For each pair of routes, Jaccard similarity was calculated as the number of shared stops divided by the number of stops appearing on either route. Route-length balance was summarised using the mean, standard deviation, and coefficient of variation of stop counts. Finally, the 12 shelter locations explicitly named in the 2024 report were compared with the 2022 stop list. Only exact matches or clear, unambiguous name matches were counted.

The analysis covers the four routes documented in the source report. Data cleaning, matrix construction, and calculations were carried out in Python 3. Because the route lists are not a probability sample, inferential tests such as regression and ANOVA were not used. The available sources also lacked a validated set of stop coordinates and a complete timetable. For that reason, the study did not calculate walking buffers, travel times, spatial autocorrelation, or hotspot statistics. The analysis is limited to topological availability and overlap in the documented route lists. This distinction matters because the presence of a stop or a route does not, on its own, demonstrate that people can reach it easily or feel safe using it (Giannotti et al., 2022).

Table 2. Variables, definitions, units and data sources

Variable	Operational definition	Unit	Scale	Source	Year
Route-stop call	One named stop appearing on one documented route	count	Route	Amar Ujala route list	2022
Unique stop	Standardized named stop appearing at least once	count	Network	Derived from route list	2022
Stop service frequency (f_j)	Number of the four routes serving stop j	1–4	Stop	Derived incidence matrix	2022

Variable	Operational definition	Unit	Scale	Source	Year
Route redundancy ratio	Total route-stop calls / unique stops	ratio	Network	Derived	2022
Jaccard similarity	Shared stops / union of stops for a route pair	0–1	Route pair	Derived	2022
Female population	Women in Moradabad Municipal Corporation	persons	M Corp.	Census PCA	2011
Safety-support infrastructure	Lighting, ICCC, shelters and bicycle-sharing facilities	documented count/function	City/project	Moradabad Smart City / local reporting	2023–2024

Note. Census population figures are used for context only; the study does not assume that municipal boundaries coincide with the service area of the documented routes.

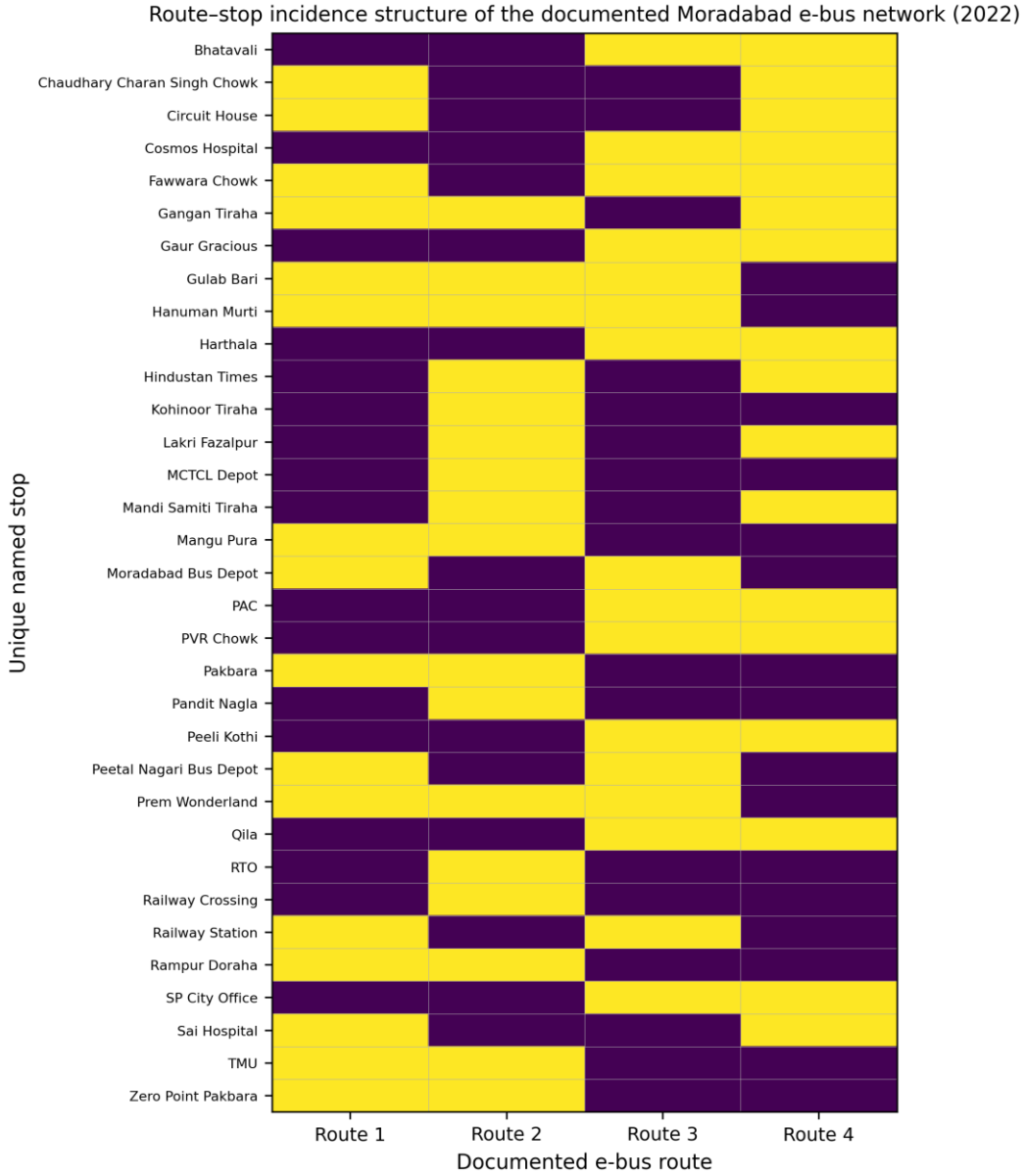


Figure 2. Route–stop incidence structure of the documented Moradabad e-bus network (2022).
Source: Author's analysis of the four route stop-lists reported by Amar Ujala (2022). This is a topological matrix, not a GIS map or distance surface.

IV. Results

The four documented routes account for 66 route–stop calls across 33 unique named stops, giving a network redundancy ratio of 2.00. Route lengths were similar: Routes 1 and 3 each listed 16 stops, while Routes 2 and 4 each listed 17. The average route contained 16.5 stops (SD = 0.58; CV = 3.50%). This similarity describes route length, but it does not show whether the routes provide balanced geographical coverage.

The stop-frequency results show that routes share many of the same locations. Of the 33 unique stops, 23 (69.7%) appeared on two routes, five (15.2%) appeared on three routes, and five (15.2%) appeared on only one route. In total, 84.8% of stops were served by at least two of the four routes. The mean route frequency was 2.00 per stop (SD = 0.56; CV = 28.0%), and the Gini coefficient was 0.129. This relatively low value indicates that route counts are fairly evenly distributed across the named stops. It should not, however, be read as proof of balanced citywide access: repeated stops may still be concentrated along the same corridors.

The pairwise Jaccard results show that route overlap varies substantially. Routes 3 and 4 had the greatest overlap, sharing 10 stops (J = 0.435). Routes 1 and 2 shared nine stops (J = 0.375), while Routes 2 and 3 had the lowest overlap, sharing three stops (J = 0.100). Across all six route pairs, mean similarity was 0.250 (SD = 0.136), with values ranging from 0.100 to 0.435. This pattern is consistent with two stronger corridor groupings rather than uniform integration across all routes. Routes 1 and 2 are associated with the western/Pakbara–TMU direction, while Routes 3 and 4 serve the Harthala–Bhatavali direction. Central locations such as Fawwara Chowk and Gangan Tiraha provide additional points of overlap between corridors.

The 2024 shelter report provides a second layer of infrastructure information. Eight of the 12 named existing e-bus shelter locations (66.7%) matched stops in the 2022 route list: Gulab Bari, Hanuman Murti, Peetal Nagari, Railway Station, Fawwara Chowk, Cosmos Hospital, Gangan Tiraha, and Chaudhary Charan Singh Chowk. This is a comparison of place names in two documents, not an estimate of the proportion of stops with shelters. The 2024 report also referred to the construction of 35 new shelters.

Moradabad's documented infrastructure includes features that may support safer or more convenient journeys, but these should not be mistaken for direct evidence of safety. The 2023 Smart City presentation lists 20 solar high-mast lights at junctions and public places, alongside round-the-clock ICCC monitoring and traffic management. It also records 34 public bicycle/e-bike stations and 300 bicycles, which could provide additional first- and last-mile options. The sources do not establish whether women feel safer as a result, whether women's ridership has increased, or whether incidents of harassment have declined.

Table 3. Route-level descriptive statistics

Route	Stop calls	Share of 66 calls	First listed stop	Last listed stop
Route 1	16	24.2%	Rampur Doraha	TMU
Route 2	17	25.8%	Rampur Doraha	TMU
Route 3	16	24.2%	Prem Wonderland	Bhatavali
Route 4	17	25.8%	Mandi Samiti Tiraha	Bhatavali
Network summary	16.5 mean	SD 0.58; CV 3.50%	66 route-stop calls	33 unique stops

Note. The source labels Routes 1 and 2 as serving the Pakbara/TMU corridor and Routes 3 and 4 as serving the Harthala/Bhatavali corridor. Stop counts are not estimates of unique population catchments.

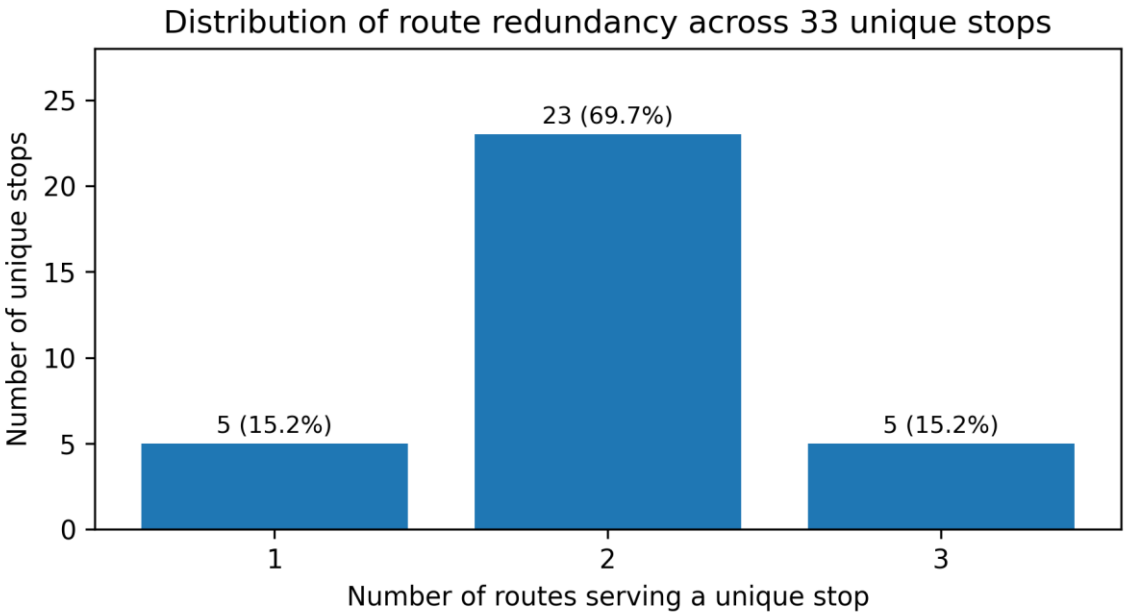


Figure 3. Distribution of route redundancy across the 33 unique documented stops.
Source: Author's calculations from the 2022 route–stop incidence matrix.

Table 4. Stop-level redundancy and pairwise route overlap

Component	Statistic	Count / basis	Percentage	Jaccard / Gini
Route-frequency distribution	1 route	5	15.2%	—
Route-frequency distribution	2 routes	23	69.7%	—
Route-frequency distribution	3 routes	5	15.2%	—
Route 1–Route 2	shared/union	9 / 24	—	0.375
Route 1–Route 3	shared/union	7 / 25	—	0.280
Route 1–Route 4	shared/union	5 / 28	—	0.179
Route 2–Route 3	shared/union	3 / 30	—	0.100
Route 2–Route 4	shared/union	4 / 30	—	0.133
Route 3–Route 4	shared/union	10 / 23	—	0.435
Network	redundancy ratio	66 / 33 = 2.00	84.8% stops on ≥2 routes	Gini = 0.129

Note. Mean pairwise Jaccard = 0.250 (SD = 0.136; range = 0.100–0.435). Gini refers to the distribution of route frequency across unique stops.

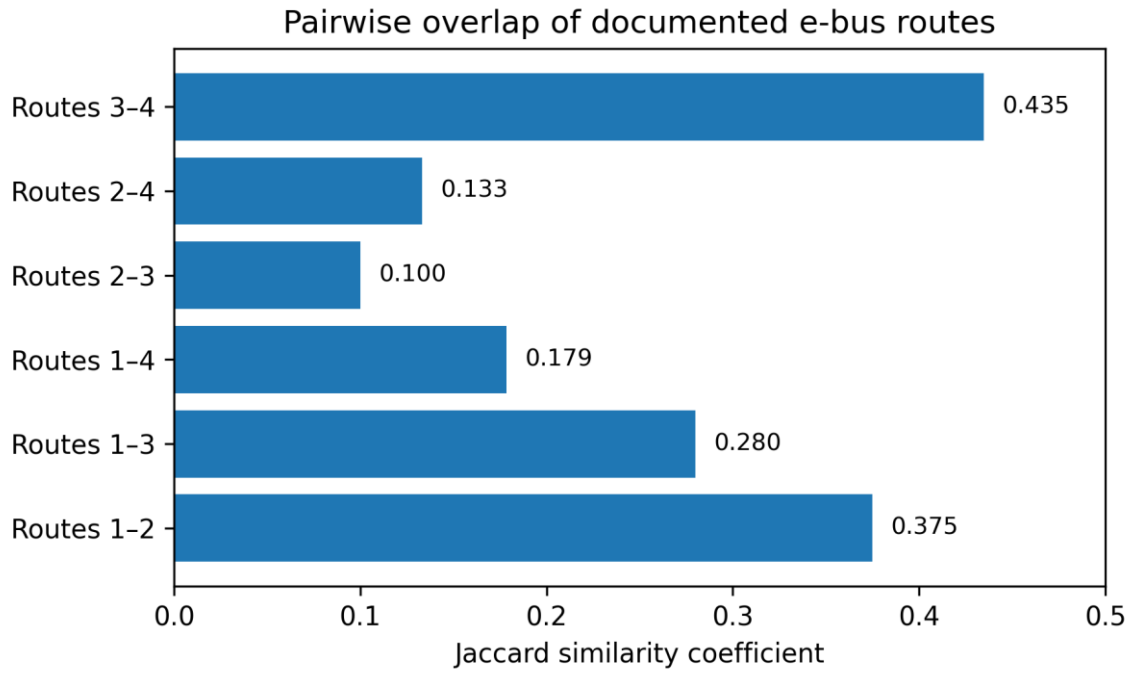


Figure 4. Pairwise Jaccard overlap among the four documented e-bus routes.
Source: Author's calculations. J = shared stops divided by the union of stops for each route pair.

Table 5. Documented transport and safety-support infrastructure

Infrastructure	Documented scale	Mobility function	Interpretive relevance	Source
Solar high-mast lighting	20 junctions/public places	Locations lacking alternative night lighting	Visibility around public space; not a safety-outcome measure	MSCL, 2023
E-bus charging station	7 charging points; 2 nodes each; 14 buses simultaneously	Operational support for electric fleet	Service reliability infrastructure	MSCL, 2023
Public bicycle/e-bike sharing	34 stations; 300 bicycles	First/last-mile connection potential	Potential access extension; gendered uptake not reported	MSCL, 2023
ICCC / ITMS	24×7 surveillance/traffic-management functions	City monitoring and incident-management capacity	Potential safety-support function	MSCL, 2023
Public Wi-Fi	35 locations	Digital connectivity	Potential information/emergency communication support	MSCL, 2023
E-bus shelters	12 existing locations named; 35 modern-design stands reported under construction	Waiting environment	Eight of 12 named existing locations directly matched 2022 stop names	Amar Ujala, 2024

Note. Project counts describe documented infrastructure status/intent. They do not establish women's perceived safety, crime reduction, or walking accessibility.

V. Discussion

The results highlight the difference between having repeated service along a corridor and reaching more parts of the city. Moradabad's four documented routes have similar stop counts, and many stops are shared across routes. However, the Jaccard results show that overlap is stronger for some route pairs than for others. Repeated stops may make transfers easier or provide some route-level resilience, but they do not necessarily extend service into neighbourhoods beyond the existing corridors. This is why accessibility studies in Lucknow, Mumbai, and other cities combine transit information with population, land use, and travel-cost data rather than relying on route counts alone (Adhvaryu & Kumar, 2021; Sharma & Patil, 2021; Salih & Lee, 2022).

This distinction is especially important when considering women's journeys. Research in Delhi suggests that women's use of public transport changes by time of day (Jain & Campbell, 2022), while studies of waiting times show that feeling unsafe can shape the experience of a journey even when transport is available (Chowdhury & van Wee, 2020). Research in Delhi and Kolkata also highlights that women's mobility depends on the entire journey and on how they navigate public spaces (Joshi et al., 2022; Roy & Bailey, 2021). In Moradabad, lighting, ICCC monitoring, and bus-shelter improvements could help address visibility and waiting conditions. Their presence alone, however, is not evidence that women are safe or feel safe.

Public bicycle services may help people reach bus corridors, but this benefit depends on the conditions of the connecting journey. For women, access roads, parking, lighting, and the wider social and security environment may influence whether bicycle-to-bus transfers are practical. Research on gender-responsive transport policy cautions against assuming that technology alone will solve safety or access problems (Uteng, 2021; Forsdike et al., 2024). Affordability, reliability, and service quality also need to be considered alongside safety (Da Silva et al., 2022; Saigal et al., 2023; Sogbe et al., 2025). A fuller assessment in Moradabad would therefore require a linked spatial database containing stop coordinates, service frequency and operating hours, shelters, lighting, land use, female population distribution, gender-disaggregated ridership, and women's reported safety perceptions. The present study is narrower than a full GIS accessibility analysis, but it offers a documented starting point for future work using GTFS schedules, GPS traces, walking catchments, and travel-time measures.

VI. Policy and Planning Implications

Moradabad would benefit from a gender-responsive mobility observatory that brings transport and public-space information together. The first step is to create and maintain a verified stop register. Transport and municipal authorities could then publish standard route and stop identifiers, geocoded stop locations, service timetables, operating hours, frequency information, shelter details, and accessibility features. Once these data are reliable, GIS analysis can identify neighbourhoods with limited service or areas dependent on a single route. Those findings should be considered alongside local population patterns and women's reported travel needs.

Each e-bus stop should also be assessed as part of a complete journey, not as an isolated point on a route map. The audit should consider approach paths, road crossings, lighting, sightlines, active street frontage, seating, emergency contact information, real-time service updates, and first- and last-mile connections. Existing Smart City lighting and ICCC systems may provide a useful foundation, but their coverage should be checked against the locations and operating hours of public transport services. Authorities should also collect boarding counts by gender and conduct brief, privacy-conscious surveys on safety and comfort at different times of day. Finally, shelter provision, bicycle sharing, and e-bus services should be planned together so that gaps between modes do not leave neighbourhoods or groups of travellers poorly served (Ison & Matthewson, 2023; Noor & Iamtrakul, 2023).

VII. Conclusion

This study establishes a documentary baseline for examining women-relevant transport infrastructure in Moradabad. The four e-bus routes listed in 2022 included 66 route–stop calls and 33 distinct named stops. Although route lengths were similar, 84.8% of stops appeared on more than one route, and pairwise overlap ranged from $J = 0.100$ to 0.435. The findings indicate that route redundancy is concentrated more strongly in some corridor groupings than others. Smart City records from 2023 and a shelter report from 2024 also document investments in lighting, monitoring, bicycle sharing, and bus shelters that may support urban mobility.

The evidence does not show how safe women feel, how far households must walk to reach a stop, or whether the infrastructure has changed travel behaviour. Safety cannot be inferred simply from the presence of facilities. It depends on the combined effects of availability, practical accessibility, service quality, public-space conditions, and people's own experiences of security. The next stage should therefore link verified stop data with land use, lighting, shelter locations, service information, and gender-disaggregated evidence.

For a medium-sized Indian city, the central planning challenge is to turn separate mobility projects into a connected and measurable system that responds to different users' needs. A verified, geocoded transport feed and time-specific information about women's travel would allow researchers to conduct network-accessibility, walking-catchment, and spatial-statistical analyses that the current data do not support.

Limitations and Future Research

The study brings together sources from different years: Census 2011, the 2022 route configuration, the 2023 Smart City project inventory, and the 2024 shelter report. These sources may not describe the same service conditions at the same point in time. The absence of validated stop coordinates, a machine-readable timetable, women's travel diaries, local safety-perception surveys, and geocoded safety outcomes further limits the analysis. Route–stop relationships cannot reveal actual distances, service frequency, crowding, night-time operations, or exposure to harassment. Future research should build a GTFS/GPS-based network, link it to current ward-level demographic data, and test pedestrian and network catchments in the 400–800 metre range. Gender-disaggregated ridership data and safety-perception surveys should cover different times of day. Time-geographic analysis, participatory safety audits, and carefully contextualised crime data could then help assess whether implemented measures improve women's real-world mobility.

Data Availability and Reproducibility Statement

The study draws on publicly available secondary sources: the Census of India 2011 Primary Census Abstract and District Census Handbook, the Moradabad Smart City project presentation published in 2023, and Moradabad route and shelter reports published in 2022 and 2024. The route–stop dataset was compiled from the published stop lists, standardised, and converted into a binary incidence matrix. The statistics in Tables 3 and 4 and Figures 2–4 were calculated from these lists. No primary participant data, synthetic data, geocoded crime data, or fabricated GIS coordinates were used. The original manuscript states that source access was checked on 26 August 2026.

Ethical Considerations

Only public secondary and documentary sources were used. The study did not recruit human participants or access identifiable personal records, so institutional ethical approval was not required for the analyses reported here. Any future survey of women's safety perceptions should obtain the appropriate ethics approval and include suitable privacy protections.

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