



Spatial Assessment of Household Perceptions of Urban Infrastructure and Basic Municipal Services in Prayagraj City, India

Amit Kumar Tiwari¹, Prof. A. R. Siddiqui²

¹Research Scholar, Department of Geography, University of Allahabad, Prayagraj, U.P, India

²Professor, Department of Geography, University of Allahabad, Prayagraj, U.P, India

Email: amittiwari6787.au@gmail.com

Abstract

Rapid urban growth creates increasing demand for roads, drainage, sewerage, waste management, water supply, street lighting, parking, green spaces and other municipal services. Understanding how residents experience these services is important for inclusive urban planning. This study examines household perceptions of urban infrastructure and basic municipal services in Prayagraj City, Uttar Pradesh. Primary data were collected from 384 households between September 2024 and January 2025. The sample was distributed equally across eight municipal zones, with 48 households from each zone. Ten major municipal problems were examined: roads and maintenance, drainage, solid waste management, sewerage, street lighting, parking, parks and green spaces, encroachment, water supply and public toilets. Descriptive percentage analysis was combined with Pearson's Chi-square test and Cramer's V to examine whether reported municipal problems varied significantly across zones. Roads and maintenance were reported by 53.9 percent of households, in drainage (49.7 percent) and solid waste management (49.5 percent). Sewerage was reported by 44.0 percent, street lighting by 42.7 percent, parking by 41.1 percent, parks and green spaces by 40.1 percent, encroachment by 35.2 percent, water supply by 30.2 percent, and public toilets by 25.0 percent. However, the Chi-square analysis did not identify a statistically significant association between municipal zone and any of the ten reported problems at the 5 percent level. Cramer's V values ranged from 0.101 to 0.174, indicating weak associations. The results suggest that municipal service concerns are broadly distributed across Prayagraj rather than being statistically concentrated in one particular zone.

Keywords: Urban transformation; Municipal services; Household perception; Urban infrastructure; Prayagraj; Spatial variation; Chi-square; Cramer's V; Urban planning

1. Introduction

Urbanisation is one of the major geographical processes shaping contemporary cities. The expansion of built-up areas, increasing population concentration, changing land use, growth of transport networks and increasing economic activities create new demands for urban infrastructure and public services. Roads, drainage, sewerage, water supply, waste management, street lighting, parking and public open spaces are essential components of urban quality of life. However, the availability of infrastructure does not always mean that residents experience services equally or satisfactorily. In India, urban growth has been accompanied by considerable differences in access to basic amenities between households and neighbourhoods. Research on water, sanitation and hygiene services in Indian metropolitan cities has demonstrated substantial spatial and socioeconomic inequalities, with intra-city inequalities in some cases exceeding inter-city differences (Saroj et al., 2020). Such inequalities can occur not only between cities but also within the same urban area. The experience of urban services is also influenced by residents' expectations and perceptions. A road may exist, for example, but households may consider it poorly maintained. Similarly, a drainage network may be present while residents continue to experience waterlogging.

Household perception therefore provides an important complementary source of information for understanding urban service conditions. It captures the everyday experience of residents and can identify problems that may not be fully visible through administrative statistics. Citizen satisfaction and feedback can reflect the relationship between the availability of services, their accessibility, quality and residents' expectations. Consequently, perception data should not be treated as a direct physical measurement of infrastructure quality; rather, they provide an important social dimension for understanding how urban services are experienced by residents. This distinction is particularly relevant in geographically heterogeneous cities where infrastructure provision and actual service experience may vary considerably across neighbourhoods. The issue is particularly relevant in rapidly transforming cities, where changes in land use, population distribution and infrastructure can produce uneven patterns of urban development. Zone-wise or neighbourhood-level analysis can therefore provide a more detailed understanding of the spatial distribution of perceived service problems.

Prayagraj City provides an important setting for examining these issues. The city is an important administrative, educational, cultural, religious and transportation centre of Uttar Pradesh and has experienced substantial urban and infrastructural change. The city has undergone significant infrastructure development associated with the hosting of large-scale religious gatherings, particularly the 2019 Kumbh Mela. Recent research based on land-use/land-cover analysis found notable changes

in Prayagraj between the pre-Kumbh, Kumbh and post-Kumbh periods, including an increase in built-up land and changes in vegetation, fallow and agricultural areas. The study also documented infrastructure interventions such as road widening, construction of overbridges, railway-related improvements and development around the airport and other transport facilities (Yadav et al., 2024). The Prayagraj Municipal Corporation is responsible for a range of civic functions, including sanitation, water supply, public health, parks, local planning and other public services. At the same time, residents continue to interact with everyday municipal services such as roads, drainage, waste management, sewerage, lighting and public spaces. This combination of rapid urban transformation and everyday service experience makes Prayagraj an appropriate case for examining spatial variations in residents' perceptions of urban infrastructure and municipal services.

2. Literature Review

Urban infrastructure and basic municipal services are central to the functioning and sustainability of cities. Conurbation raises the demand for roads, drainage, sanitation, water supply, waste disposal, public transport, lighting and open spaces. A lack of infrastructure growth can lead to congestion, poor drainage, waste build-up and sanitation challenges for residents during periods of land-use change and population growth. Kumar (2015) studied the access to basic amenities to urban households in India and found that there are longstanding gaps between access to basic services. The study shows that urban development does not lead necessarily to the equal access to infrastructure and that the accessibility to services depends on the characteristics of the households and the spatial situation.

But many studies have focused on the fact that urban inequality is also present within the city. Bharathi et al. (2022) investigated the landscape of urban residential segregation and public services access in urban India, and demonstrated the potential link between spatial and social inequalities with access to essential services. These results are significant as average values at the city level may mask significant variations between neighbourhoods. In another enquiry about water, sanitation and hygiene services in metropolitan cities of India, Saroj and colleagues (2020) found significant intra-city disparities. Their conclusions suggest that a way to move forward in assessing urban service beyond the city-to-city comparison must take on the issue of intra-urban variation.

The quality of municipal services is also closely connected with residents' perceptions. While administrative data typically assess infrastructure coverage and expenditure or physical availability, household surveys can provide a picture of how services are actually used in daily life. Van Ryzin et al. (2004) demonstrated the feasibility of assessing citizen satisfaction systematically through public-service evaluation, and later Van Ryzin and his colleagues emphasized the importance of expectations and comparisons in determining residents' evaluation of local government services. Perception is

therefore not the same as objective infrastructure quality but offers a valuable social aspect of the measurement of urban services.

Particularly, in the Indian urban context, basic services like water supply, sanitation and drainage have been given due attention. Kundu et al (2024) spoke about how the urban poor has access to basic services and also raised some concerns regarding sustainability and equity. They highlight the continuing need to look at access to, adequacy and equity of urban services. The lack of access to water and sanitation services also has clear implications for the well-being of the household and is a key indicator of urban quality of life. Another serious issue is solid waste management in the fast-growing Indian cities. The population growth, consumption and commercial activity will cause the production of more and more municipal waste with implications on collection, transportation, segregation and disposal systems. The Sharholly et al. (2008) have made review on the Municipal Solid Waste Management in Indian Cities and found the institutional, technical and management challenges. More recent reviews have also highlighted the need for waste collection, segregation, treatment and disposal to be improved. At the household level, the frequency of waste collection and the size of collection bins, as well as the presence of waste in the neighbourhood, can be significant indicators of a lack of municipal services.

In addition, the quality and liveability of cities are contributed by urban green spaces and public facilities. Environmental and social conditions are enhanced when the street is designed with parks, open spaces and recreational facilities and when lighting is designed to enhance safety and convenience, and when parking is designed to enhance mobility. Such facilities may become inaccessible and unavailable as a result of urban transformation, especially when urban development is rapid. Thus, urban service assessment should not only encompass traditional infrastructure like roads and water, but public spaces and environmental amenities as well.

Prayagraj has been working more and more on urban transformation and alteration in land use and morphology. The connection between cultural events and land-use transformation and the changing spatial structure of the city have been recently discussed. But little focus has been placed on the perceptions of residents' attitudes towards municipal services in the various administrative areas of the city. Very little is known, too, about whether the differences in residents' perceptions of municipal problems are statistically significant.

3. Research Gap

Existing studies provide substantial evidence on urban infrastructure, basic services and spatial inequality in Indian cities. However, comparatively limited research combines household perception with zone-level statistical testing for municipal services in Prayagraj. The present study addresses this

gap by examining ten municipal problems across eight zones and testing whether zone-based differences are statistically significant.

4. Objectives

1. To examine household perceptions of major urban infrastructure and municipal service problems in Prayagraj City.
2. To analyse the spatial variation and major municipal service problems reported by households across the eight municipal zones of Prayagraj City.

5. Data Sources and Methodology

5.1 Primary Data and Sampling

The study is primarily based on a household survey conducted between September 2024 and January 2025. Households were selected using a simple random sampling method to ensure that each household had an equal opportunity of being included in the sample. A total of 384 households were included in the analysis. The sample was distributed equally among eight municipal zones, with 48 households from each zone. The survey recorded household responses concerning major municipal and urban service problems. Secondary information from municipal and government documents, academic literature and relevant planning materials was used to provide the geographical and institutional context.

5.2 Statistical Analysis

Descriptive percentages were calculated to identify the frequency of reported municipal problems. Pearson's Chi-square test of independence was then applied separately to each municipal problem using an 8×2 contingency table, consisting of the eight municipal zones and two response categories, namely reported and not reported. The Pearson Chi-square statistic was calculated as Equation (Eq.1):

$$\chi^2 = \sum_{i=1}^r \sum_{j=1}^c \frac{(O_{ij} - E_{ij})^2}{E_{ij}} \dots \dots (1)$$

where O_{ij} represents the observed frequency and E_{ij} represents the expected frequency in the i, j th cell of the contingency table. The Chi-square statistic evaluates the extent to which the observed frequencies differ from those expected under the assumption of independence between the categorical variables (Agresti, 2002; Kim, 2017).

The expected frequency for each cell was calculated Eq. 2 as:

$$E_{ij} = \frac{R_i C_j}{N} \dots \dots (2)$$

where R_i is the total frequency of the i th row, C_j is the total frequency of the j th column, and N is the total number of observations.

The degrees of freedom were determined using Eq. 3:

$$df = (r - 1)(c - 1) \dots \dots (3)$$

For the present 8×2 contingency table following Eq. 4:

$$df = (8 - 1)(2 - 1) = 7 \dots \dots (4)$$

Statistical significance was evaluated at the 5 percent significance level ($\alpha = 0.05$). A p -value below 0.05 was considered evidence of a statistically significant association between municipal zone and the reported municipal problem.

Because statistical significance alone does not indicate the magnitude of an association, Cramer's V was used as an effect-size measure. Cramer's V is appropriate for assessing the strength of association between categorical variables in an $r \times c$ contingency table (Cramér, 1946; Akoglu, 2018).

The formula is Eq. 5:

$$V = \sqrt{\frac{\chi^2}{N[\min(r, c) - 1]}} \dots \dots (5)$$

where V is Cramer's V , χ^2 is the Pearson Chi-square statistic, N is the total sample size, and r and c represent the number of rows and columns, respectively. Cramer's V ranges from 0 to 1, with values closer to zero indicating weaker association and values closer to one indicating stronger association.

For the present 8×2 table, $\min(r, c) - 1 = 1$; therefore Eq. 6:

$$V = \sqrt{\frac{\chi^2}{N}} \dots \dots (6)$$

Cramer's V was calculated for each of the ten municipal problems to assess the strength of association between municipal zone and household-reported problems.

6. Results and Discussion

6.1 Overall Household Perception of Municipal Problems

The Table 1. show that roads and maintenance were the most frequently reported municipal concern, identified by 53.9 percent of households. Drainage and solid waste management followed at 49.7 percent and 49.5 percent, respectively. Sewerage was reported by 44.0 percent of households, while street lighting, parking and parks/green spaces were reported by 42.7 percent, 41.1 percent and 40.1 percent, respectively. Encroachment was reported by 35.2 percent, water supply by 30.2 percent, and public toilets by 25.0 percent. The pattern indicates that households experience municipal problems across several dimensions rather than a single service category.

Table 1. Ranking of Municipal Problems Based on Household Perception in Prayagraj City

Rank	Municipal problem	Households reporting (%)
1	Roads and maintenance	53.9
2	Drainage	49.7
3	Solid waste management	49.5
4	Sewerage	44.0
5	Street lighting	42.7
6	Parking	41.1
7	Parks/green spaces	40.1
8	Encroachment	35.2
9	Water supply	30.2
10	Public toilets	25.0

Source: Researchers calculated based on Primary Household Survey, Prayagraj City, 2024-2025

6.2 Pearson's Chi-square and Cramer's V

The Pearson's Chi-square results Table 2. show that none of the ten municipal problems has a statistically significant association with municipal zone at the 5 percent significance level. The descriptive percentages vary among the zones but all the p-values are above 0.05. The Cramer's V values lie between the range of 0.101-0.174 which show weak associations. The outcomes of this study, therefore, indicate that municipal service concerns are widely spread throughout the city as opposed to being statistically concentrated in one zone of the city.

Table 2. Chi-Square Test of Association Between Municipal Zone and Reported Municipal Problems in Prayagraj City

Municipal problem	χ^2	df	p-value	Cramer's V	Decision
Roads & maintenance	6.278	7	0.508	0.128	Not significant
Drainage	5.573	7	0.590	0.120	Not significant
Solid waste management	9.959	7	0.191	0.161	Not significant
Sewerage	8.021	7	0.331	0.145	Not significant
Street lighting	11.580	7	0.115	0.174	Not significant
Parking	10.109	7	0.182	0.162	Not significant
Parks/green spaces	6.028	7	0.537	0.125	Not significant
Encroachment	3.918	7	0.789	0.101	Not significant
Water supply	7.312	7	0.397	0.138	Not significant
Public toilets	11.556	7	0.116	0.173	Not significant

Source: Researchers calculated based on Primary Household Survey, Prayagraj City, 2024-2025

7. Discussion

The results of the present study reveal that there are a series of concerns related to urban infrastructure and municipal services in Prayagraj, and not just one type of service. Of the top ten municipal problems, roads and maintenance was the most common (53.9 percent), followed by drainage (49.7 percent) and solid waste management (49.5 percent). Sewerage was reported by 44.0 percent of households, street lighting (42.7 percent), parking (41.1 percent) and parks and green spaces (40.1 percent) were also reported by significant proportions of residents. The most prevalent problems reported by the households were encroachment (35.2 percent), water supply (30.2 percent) and public toilets (25.0 percent). This pattern indicates that the perception of quality of urban service is influenced both by the traditional basic services, and by the broader aspects of urban livability.

The fact that roads and maintenance are the top concern signals the significance of mobility infrastructure in citizens' daily life in the city. Roads are one of the most noticeable and common components of urban infrastructure and directly affect accessibility, transportation of people/goods and travel. The discovery is significant in the context of Prayagraj, where a lot of infrastructure development has taken place in connection with big events like the Kumbh Mela in 2019. Yadav et al. (2024) documented the changes in the morphology of the city of Prayagraj during the period of Kumbh and the land use changes such as widening of the roads, construction of overbridges and improvement of transport infrastructure. In addition to this, the expansion of such infrastructure can bring additional benefits for connectivity and create ongoing needs for traffic control and encroachment control. Thus,

the relatively high perception of road-related problems needs to be interpreted as an experience of road condition and maintenance in their residents' lives and not as an absence of roads.

The second most common concern reported was drainage (49.7 percent). As urban areas grow, natural drainage may be altered to meet increased demands and existing infrastructure may be stressed, making drainage more critical in rapidly changing urban regions. Kumar (2015) showed that access to basic urban amenities in India is still marked with disparities as per household and spatial characteristics. This current study adds to this body of work in that it indicates that drainage continues to be a significant part of residents' perceptions of urban service adequacy. The result, however, should not be viewed as an engineering estimate of drainage capacity in the house, since the present study is concerned with the perception of the house occupants.

Similarly, solid waste management was reported by 49.5 percent of households, highlighting the environmental dimension of urban service provision. As the population grows rapidly, consumption and commercial activities increase, leading to growing amounts of municipal waste in volume and complexity, and demanding more from the collection, transport, segregation and disposal systems. Kumar and Agrawal (2020) highlight that solid waste management issues in Indian cities are still existing and require better solid waste collection, treatment and disposal systems. These could be of special significance in Prayagraj when there are a high number of temporary residents, as seen during large religious gatherings. The household responses thus emphasize the need to harmonize the regular waste management by the municipality with its capacity to manage the periodic population growth and waste production.

The substantial reporting of sewerage (44.0 percent), street lighting (42.7 percent), parking (41.1 percent) and parks/green spaces (40.1 percent) also shows that residents' understanding of cities covers more than just water and sanitation, it covers mobility, safety, and environmental amenities. Bharathi et al. (2022) show that in Indian cities, access to public services can be linked to neighbourhood and residential segregation, meaning that the averages at a city level may not reflect the full diversity of neighbourhoods. The present study offers a complementary view, in that it does not only look at the access to multiple services from a physical point of view, but also considers the residents' reported experience of multiple services. The high level of perceived problems with parks and green space also applies to the urban transformation of Prayagraj, where built-up areas and vegetation changes have been recorded (Yadav et al., 2024).

An important finding of the study is that none of the ten municipal problems showed a statistically significant association with municipal zone at the 5 percent level. All variables had a p-value above 0.05 in the Chi-square distribution test and a weak association between variables with Cramer's V ranging

between 0.101 and 0.174. This indicates that there may be descriptive differences among the eight zones, but that the differences observed are not strong enough to draw any conclusion that the municipal zone is systematically related to residents' experiences of these problems. It should not, however, be concluded that there is no spatial inequality in Prayagraj. Instead, it means that the administrative zone is not statistically significant with regard to differences in the perceived municipal problems studied in this specific sample.

This result provides an interesting contrast with studies documenting substantial intra-urban disparities in Indian cities. Saroj et al. (2020) found significant disparities in WASH conditions in Indian metropolitan cities, and Bharathi et al. (2022) were able to identify linkages between residential segregation and WASH conditions. This disparity might stem partly from the distinction in the measures used in the present study of perceived municipal problems, versus these studies of availability of services. Service quality and frequency, expectations and experience are all other factors that shape perception, in addition to physical provision. Therefore, we should consider the household perception as a social indicator that must be complemented by other objective indicators of infrastructure.

The overall results have shown that the concerns of municipal services in Prayagraj are largely spread across the city and not statistically concentrated in any zone. The results indicate a planning strategy of both city-wide improvement of the service and monitoring at neighbourhood level. Roads, drainage and waste management were the most common concerns and were given special consideration. Household perception should be combined with GIS-based indicators like road density, drainage density, land-use change, accessibility to public infrastructure and objectively measured conditions of infrastructure in further studies. This holistic approach would give a holistic view of the relationship between urban transformation and infrastructure provision with residents lived experience in Prayagraj.

8. Planning Implications

The results of the findings have the implications in the field of urban planning in Prayagraj. Continued attention to roads and maintenance, drainage and solid waste management should be given as they are among the most common household concerns. Municipal monitoring should be based on both subjective indicators, like road condition, and objective indicators, like drainage capacity, waste collection frequency and coverage. The Chi-square results do not demonstrate statistically significant associations but zone-level monitoring can still be helpful as it may provide descriptive differences to help determine local priorities. Accessibility and daily life experiences should be taken into account in planning for parks, street lights, parking and sanitation.

9. Limitations

The study comments on respondents' perceptions of the condition of infrastructure rather than its actual condition. Responses may be affected by seasonal conditions, especially in regard to drainage issues. A sample of 384 households is equally distributed across eight zones, which will have more statistical power if larger. Each of the municipal problems is also explored in detail. In future research, household perception can be combined with objective measures of road density, drainage density, land-use change, distance to public facilities and other measures of infrastructure derived from GIS.

10. Conclusion

This study analysed the perceptions of households through a survey of 384 households spread across the eight zones of Prayagraj Municipal Corporation about urban infrastructure and basic municipal services. The most common concerns were roads and maintenance, drainage and solid waste management. The Pearson's Chi-square tests, however, revealed no statistically significant relationships at the 0.5 level between municipal zone and any of the ten problems studied. The Cramer's V was also fairly low. The results show that the concerns of the municipal service is not concentrated in a particular zone in Prayagraj but distributed in a broader manner. Household perception can then be used as a valuable supplement to the information an municipality can rely on for planning. Future research is recommended to combine the data from the household surveys with objective GIS and infrastructure indicators, to give a more complete picture of urban transformation and service inequality.

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