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For whom the road tolls: perceived benefits, commuter segmentation, and congestion pricing acceptability in Hyderabad

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ABSTRACT

This paper investigates commuter perceptions of congestion pricing (CP) benefits in Hyderabad, India. Previous experience suggests that limited knowledge of how users perceive CP before implementation may undermine policy adoption. Identifying and examining car users' perceived CP-related benefits constitutes a key research question. Based on a face-to-face survey yielding 435 complete responses, the study employs benefit-based commuter segmentation and Meta Ranking to identify and prioritize perceived advantages across heterogeneous user groups. Results show that, although travel-time minimization emerges as the most important perceived benefit overall, respondents are far from homogeneous, with four identified commuter segments prioritizing different benefit bundles. These findings underscore the need for a differentiated approach to policy design and communication, while also highlighting the role of stakeholder engagement and transparent revenue use to promote CP acceptability. The proposed methodology offers a scalable tool for context-specific policy analysis aimed at maximizing the ex-ante probability of acceptance.

1. Introduction

Urban congestion is one of the most relevant transport challenges faced by contemporary cities, generating substantial social, economic, environmental, and operational costs. It undermines the efficient use of existing infrastructure, increases travel times and vehicle operating costs, and reduces supply chain reliability, with negative implications for transport system efficiency and urban productivity more broadly (Struyf et al., 2022; Marazi et al., 2026). While these issues characterize many large urban areas worldwide, they are particularly acute in rapidly urbanizing developing countries such as India (TomTom, 2020). In India, the share of the population living in urban areas increased from 28.53% in 2001 to 34.93% in 2020 (Aaron O'Neill, 2020), while the number of registered vehicles rose from 141 million in 2011 to 230 million in 2016 (MOSP, 2018). Over the same period, road infrastructure expansion remained comparatively limited, with annual road length growth estimated at around 3%, far below the annual motorization growth rate of about 10% (MOSP, 2018). As a result, congestion-related externalities have intensified, including longer travel times, higher vehicle operating costs, and increased emissions (Percoco, 2021; Welch and Mishra, 2014). Major Indian cities were estimated to incur annual losses of about ₹1500 billion in 2018 due to traffic congestion, while average peak-hour commute times also increased (Dash, 2018; Indian Express, 2018).

Fig. 1 highlights the imbalance between modal share and road-space occupation in India. Private vehicles and taxis account for a relatively limited share of trips, yet absorb a disproportionately large amount of road space, whereas more space-efficient collective modes play a much

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smaller role in overall allocation. This imbalance reinforces the need for policies capable of improving the management of scarce urban road capacity and reallocating transport resources more efficiently.

Among the available transport demand management measures, congestion pricing (CP) is widely regarded as one of the most effective instruments for addressing urban congestion and its related externalities (Rivasplata, 2013; Siddique and Choudhury, 2017). In essence, CP imposes a charge on private vehicle use in congested areas to discourage inefficient trips, improve traffic flow, and promote a shift toward more sustainable modes. By internalizing part of the social costs of congestion, CP can reduce traffic levels, improve travel-time reliability, enhance air quality, and generate revenues that may be reinvested in transport infrastructure and services (Abulibdeh et al., 2015; Clements et al., 2021; Song and Li, 2012; Marazi et al., 2026). It is therefore often considered a market-based and comparatively flexible policy instrument, especially when compared with infrastructure expansion measures that require substantial land and financial resources and often produce only temporary congestion relief.

International experience provides substantial evidence of CP's potential. Schemes implemented in cities such as Singapore, London, Stockholm, Milan, and more recently New York have shown that CP can contribute to congestion reduction, improved public transport performance, enhanced environmental quality, and revenue generation (Behruz et al., 2012; Danielis et al., 2012; Phang and Toh, 2004). At the same time, however, the experience of cities such as Hong Kong, Edinburgh, and Manchester indicates that technical feasibility alone is insufficient. A lack of political and public support can prevent implementation even where congestion problems are severe. Previous research has consistently shown that public acceptability constitutes one of the key conditions for successful CP adoption (Attard and Enoch, 2011; Marcucci et al., 2005; Marcucci et al., 2018).

This issue becomes even more relevant in contexts where CP has not yet been implemented. Most existing studies examine cities in which congestion pricing is already operational or has been tested through pilot schemes. By contrast, considerably less attention has been devoted to the pre-implementation stage, namely to how potential users perceive the expected benefits of CP before the policy is introduced. This gap is important, since ex-ante perceptions may strongly influence both public support and the political feasibility of the measure. Understanding such perceptions in advance can therefore help reduce implementation risks, improve policy design, and support the development of more effective communication and participation strategies. CP is understood here as a policy instrument enacted by public authorities, not as a voluntary measure dependent on spontaneous user uptake. Its successful implementation depends not only on formal adoption, but also on ex-ante political and social acceptability, since weakly perceived or non-credible benefits may generate resistance capable of delaying, weakening, or even preventing implementation (Meng and Liu, 2012; Marcucci et al., 2005). In this respect, perceived benefits matter because they shape credibility, legitimacy, and practical implementability of the policy before and during its introduction.

This need is particularly evident in the Indian context, where CP is increasingly discussed as a possible instrument for major metropolitan areas but has not yet been introduced. In such a context, examining the perceived benefits of CP before implementation is important not only from an analytical standpoint but also from a policy design perspective. It can help identify which expected outcomes are most valued by commuters and which arguments may be more effective in fostering support. More specifically, it can provide a basis for participatory planning processes aimed at improving legitimacy, reducing resistance, and aligning the scheme with the needs and expectations of the affected population (Torrance and Froese, 2011). This is especially relevant since travellers should not be considered a homogeneous group. Different commuters may attach different importance to different possible benefits of CP, such as travel-time reduction, congestion relief, environmental improvement, public transport enhancement, safety gains, or greater departure-time flexibility.

Accordingly, a distinctive feature of this paper is its explicit focus on commuter heterogeneity. Rather than treating car users as a single undifferentiated category, the study assumes that different latent commuter segments may perceive and prioritize CP-related benefits differently. This is important from both an analytical and a policy perspective, because identifying such segments can support the design of more targeted, credible, and potentially more acceptable CP strategies. Segment-specific knowledge can help policymakers better tailor communication, participation, and accompanying measures, thereby improving the overall effectiveness of the policy intervention.

Against this background, this paper investigates commuters' perceptions of the potential benefits of congestion pricing in Hyderabad, India, by adopting an attitudinal approach. More specifically, it

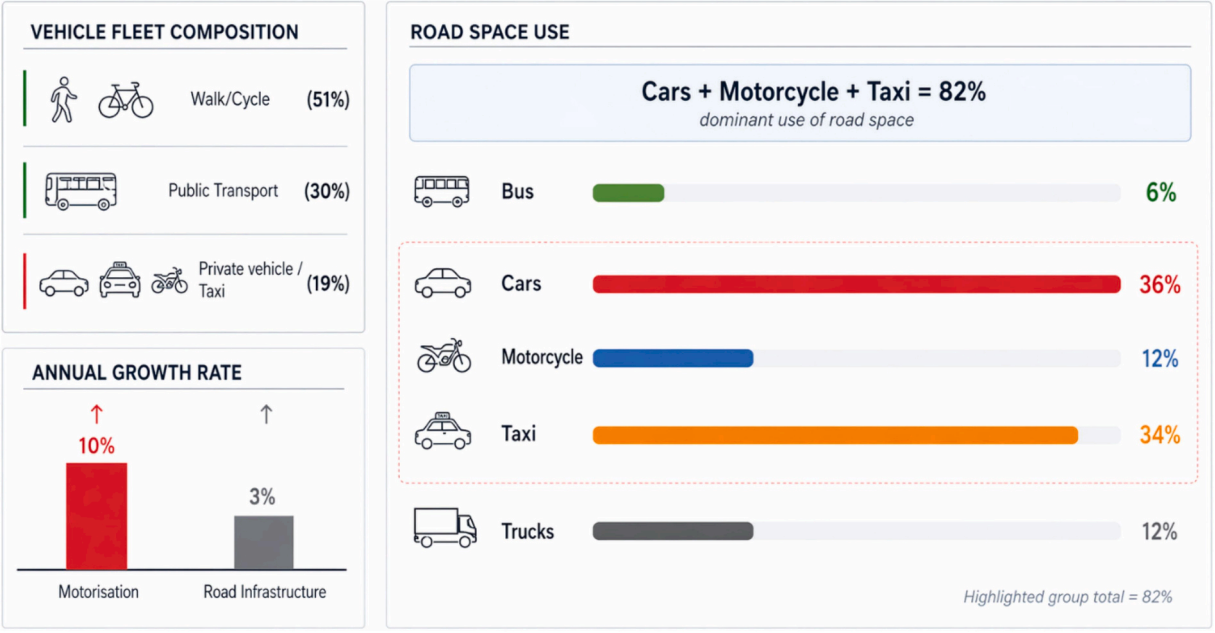

Fig. 1. Vehicle fleet composition and road space use in India.

addresses two research questions: (i) whether distinct latent commuter segments can be identified on the basis of perceived CP benefits; and (ii) how the potential benefits of CP can be prioritized across these segments to support the early design of a participatory planning process for CP in Indian cities. By combining benefit-based segmentation with benefit prioritization, the paper seeks to provide evidence that can support the formulation of more nuanced and context-sensitive CP strategies.

Hyderabad constitutes an appropriate case study for this purpose. As one of India's fastest-growing metropolitan areas, it faces acute congestion, rapid motorization, and mounting environmental pressures. These characteristics make it a particularly relevant context in which to examine the ex-ante perceived benefits of CP. Overall, the paper contributes to the literature by focusing on a pre-implementation setting in a large developing-country city and by showing that the perceived benefits of CP are not uniform across commuters. Understanding such heterogeneity represents a necessary first step toward designing congestion pricing policies that are not only technically sound, but also socially and politically implementable.

The remainder of the paper is structured as follows. Section 2 reviews the literature on congestion pricing and its perceived benefits. Section 3 presents the study area, survey design, and analytical framework. Section 4 discusses the empirical results. Section 5 outlines the related policy implications. Section 6 concludes by summarizing the main findings and acknowledging the study limitations.

2. Literature review

CP can generate a range of benefits for users and operators by reducing stress, improving trip predictability, and, in some cases, enabling more efficient trip scheduling (Devaraj et al., 2020; Parry, 2009). Privatization of road infrastructure has also been found effective in increasing the revenue base and improving the efficiency of land allocation, although such gains must be balanced against toll collection costs and equity implications (Anas, 2020; Junge and Levinson, 2013). By increasing speed and reliability, raising transit usage, and reducing operating costs, CP may also support the performance of mass transit systems. CP can also benefit state and local governments by improving transport service quality without requiring major capital expansion, while generating revenues for future transport investment (USDOT, 2022). It may also reduce emergency response times, preserve network throughput, and help identify where future transport investments should be concentrated. In addition, CP can reduce fuel consumption and emissions, encourage more efficient land use, and support broader social welfare gains (USDOT, 2022). Regardless of these potential advantages, a CP scheme cannot succeed without broad public support. Stakeholder engagement, transparent communication, and participatory planning are important in reducing resistance and improving acceptability. Along these lines, de Oliveira et al. (2019) identify revenue use as a critical issue, particularly when revenues are allocated to public transport and non-motorized infrastructure. Schade and Baum (2007) report that attitudinal evaluations strongly affect the introduction of road pricing schemes. Marcucci (2001), Marcucci and Marini (2003), and Marcucci et al. (2005) likewise emphasize the role of uncertainty and policy acceptability in shaping support for CP.

This section provides a critical review of the existing literature. It is organized into three parts. The first identifies the potential benefits associated with CP, also considering past implementations. The second and third briefly review segmentation and prioritization techniques. The section concludes by summarizing the main research needs emerging from the literature.

2.1. Potential perceived benefits of CP

In what follows, the paper discusses the potential perceived benefits influencing CP users' perceptions using the elements emerging from the literature review as a starting point.

Congestion reduction: the main objective of any CP scheme is to reduce traffic in the most vulnerable city zones (TfL, 2008). CP has successfully reduced congestion in London, Milan, and Singapore. Congestion reduction is perceived as a direct benefit of CP that improves perceived trip quality (i.e., reduced travel time and cost, etc.) (Marazi et al., 2024).

Travel-time minimization: CP implementation can lead to decreased travel time for the same journey due to a reduced number of vehicles on the road. This effect would also improve the associated reliability (Schuitema et al., 2010).

Improvement of public transport: CP adoption would generate substantial revenues, which could be invested to improve public transport service quality and overall public transport operations. The anticipated improvement in public transport has been identified as a crucial factor in public acceptance of CP schemes (Marazi et al., 2026; Santos, 2005). As in London, CP decreased bus delays by 50%, and, consequently, transit ridership increased by 7% (TfL, 2008).

Safety improvement: the safety of road users other than car commuters has always been a key goal for transportation planners. A review of CP implications reports that crashes significantly dropped in both London and Stockholm zones, where CP was implemented, compared to other zones. The review also reports that the number of crashes in non-charging zones adjacent to the charging zone also dropped following CP implementation. Balwani and Singh (2009) project a significant decrease in crashes using simulated data under CP. Before CP implementation, cities must consider the safety implications of the modal shifts. The income generated from CP can improve safety conditions for the road sector by providing the resources necessary to deploy road-related improvements such as traffic signs, traffic signals, pedestrian sidewalks, and protected bicycle lanes (Schaller, 2010), which in turn can increase nonmotorized trips.

Environment quality improvement: CP significantly improves environmental quality. Rotaris et al. (2010) report that CP in Stockholm has resulted in environment and traffic safety improvements valued around €23 million. Thus, CP can reduce the local impacts (pollution, visual intrusion), regional impacts (secondary pollutants, ozone depletion, and acid rain formation), and global impacts (contribution to generating carbon emissions) concerning transportation sector. Hence, air quality improvement is a key benefit of implementing CP (Marazi et al., 2022; Souche-Le Corvec et al., 2019).

Departure time flexibility: Departure time can be distinguished into (i) actual departure time and (ii) preferred departure time. Due to traffic congestion, one may have to start a trip earlier than the preferred departure time in order to maintain workplace punctuality (van Amelsfort, 2009). CP implementation may help decongest the road network, allowing commuters to depart closer to their preferred time, which may also free time for other activities (Marazi et al., 2023).

Crash reduction: Studies also consider congestion one of the main reasons for crashes, as stop-and-go traffic affects driving behaviour and reduces driver patience, resulting in accidents. Implementing CP improves travel speed and reduces travel time, which can help minimize the probability of being involved in a crash (Zheng et al., 2010). Singichetti et al. (2021) report that CP is associated with a 27% reduction in traffic crashes over the two years following implementation in London and a 33% reduction in Milan. In the London case, however, the authors also estimate 40–70 additional crashes per year relative to the reduction expected before implementation on the basis of pre-existing road safety measures and the general downward trend in road traffic crashes.

Active-mode promotion: CP can encourage using other active modes of transport. In the United Kingdom, CP successfully increased bicycle and walking trips and reduced vehicular trips (TfL, 2008). Planning agencies should consider a major goal: increased CP-induced cycling and walking (Brown et al., 2015). Active-mode promotion may attract pro-environmental commuters and could increase the scheme's reach.

2.2. Segmentation and prioritization

Since understanding preference heterogeneity is crucial for the implementation of any new policy, the identification of latent commuter segments in the population can help formulate policies with lower public and political resistance. Segmentation makes it possible to account for preference heterogeneity by dividing the population into meaningful subgroups. In this study, latent class analysis (LCA) is used to segment commuters according to their perceptions of CP-related benefits, followed by attribute prioritization across the different commuter classes. A successful CP scheme depends not only on pricing mechanisms, locational attributes, and the quality of the parallel public transport system, but also on the benefits perceived by commuters. Policymakers should therefore identify and prioritize the benefits associated with CP in order to better match commuter expectations and improve acceptability. Prioritization establishes the relative importance of the different characteristics under consideration. An effective ranking methodology can identify the most and least important perceived benefits in the present case. Identifying these key benefits can assist policymakers in designing more effective CP strategies by clarifying which outcomes are most relevant for different segments. Several techniques have been used to identify the most important attributes within a reference group. Among them, Multi-Criteria Decision Making (MCDM) methods are widely used for attribute prioritization. MCDM can assist researchers in prioritizing alternatives while accounting for car users' heterogeneous preferences (Moradpour and Long, 2019). These techniques are suitable for a wide range of real-world problems and can use user perception data collected through five- or seven-point Likert scales to estimate attribute scores and derive rankings. Despite the evidence supporting the successful application of various MCDM techniques, reliance on a single MCDM method may be weak where ranking consistency is a priority (Patil and Majumdar, 2021). Because of differences in the assumptions and theoretical frameworks underlying each MCDM method (Abrantes and Wardman, 2011; Patil and Majumdar, 2022; Peng et al., 2011), the rankings generated by different methods may vary even for the same dataset. In such cases, advanced optimization techniques can be used to obtain aggregated prioritized rankings (Mohammadi and Rezaei, 2020) and accommodate possible trade-offs (Peng et al., 2011). An aggregated ranking technique can therefore help determine a more consistent prioritized order of CP-associated benefits influencing commuters' perceptions.

3. Research motivation

The literature on past CP implementation suggests that CP may benefit various stakeholders by reducing travel time and delays (Li et al., 2010). Ample evidence supports its role in increasing transit ridership, lowering transit operating costs, enhancing transit speeds and reliability, reducing vehicular emissions, and reducing the number of crashes. CP has also been cited as a tool that can improve highway service efficiency without raising general taxes or requiring major capital investments, while generating resources for transport improvements and reducing emergency response time for emergency interventions. However, the literature also shows that financial and technical issues are not the only barriers to implementation. Rather, lack of public acceptance remains a critical constraint (Marcucci et al., 2005; Oakil et al., 2016). Schade and Schlag (2003) report that social norms positively influence acceptability, personal outcome expectations, and the perceived effectiveness of CP. Geng et al. (2021) examine how CP affects business relocation decisions in Beijing and identify a range of personal, household, job-related, residential, commuting, freight, social, and policy-related factors shaping responses to the scheme. In this respect, the benefits associated with CP need to be clearly identified and credibly communicated if the policy is to gain broader support.

In what follows, the paper provides a set of key observations derived from a brief CP-focused literature review. All the available literature is based on studies conducted in cities where CP is already implemented or tested as a pilot project (Hensher and Li, 2013; Jaensirisak et al., 2005; Nikitas et al., 2018; Selmoune et al., 2020). A handful of previous studies have investigated commuters' perceptions of the expected benefits attributable to a CP scheme in a pre-implementation stage. This paper first identifies the various latent commuter segments based on perceptions of the various CP-related perceived benefits and later prioritizes the perceived benefits for different segments for initiating a CP participatory planning process that would, most likely, make its actual adoption likely. Hence, the key benefits identified in this study can serve as guidelines for policymakers and the local governing bodies planning to design CP schemes for Indian cities. Furthermore, while many studies have listed potential benefits derived from CP implementation, they rarely provide their prioritization, which, in a case like India, is fundamental given that CP has never been implemented.

4. Methods

This study focuses on commuter segmentation and benefit prioritization to provide policymakers with preliminary evidence to support participatory planning for CP in major Indian cities. Following data collection, the database was segmented into classes using LCA, and the probability of agreement associated with different perceived benefits was also computed. The perceived benefits of CP were then prioritized across the different segments using Meta Ranking techniques. Fig. 2 illustrates the methodological framework adopted in the study.

4.1. Latent class analysis (LCA)

Heterogeneity is a significant issue for transportation studies. Many researchers address this issue by segmenting the data based on experts' opinions. However, researchers should test homogeneity rather than assume it. LCA was initially introduced to this end (Bhat, 1997) by computing two parameter sets: class membership likelihoods and item-response likelihoods. LCA provides a method that estimates and removes the measurement error from the vector of latent-class membership probabilities. Using LCA for categorical data avoids making any assumption regarding the distributions of the indicators (perceived benefits) other than local independence, thus making the indicators independent within a latent class. Local independence is equivalent to assuming uncorrelated uniqueness. Interrelationships between indicators in the dataset are expected, and the latent class variable is meant to account for these interrelationships (see Fig. 2).

LCA identifies homogeneous segments within a large and heterogeneous database and, in our case, addresses the issue of commuter heterogeneity with respect to CP benefits. Fundamentally, LCA reveals unobserved commuter segments in the sample whose members have similar perceptions of CP benefits within each segment but differ between segments (Pani et al., 2020). In this study eight statements were used to estimate the LCA model. In the best clustering solution, each attitudinal statement in the LCA is assigned a probability value belonging to each resulting segment, where values total one within a particular class (see Appendix A).

Given the sample data of CP-associated perceived benefits, suppose there are n_l number of latent classes to be estimated based on the y statements. Let the vector $K_i = (K_{i1}, \cdots K_{iy})$ represent the respondent *i*'s response to the y^{th} statement, where the values of K_{iy} can be $1 \ldots Z_y$. Let $Lc_i = 1, 2, 3, \cdots, n_x$, be the membership of response *i;* and let $I(k = q)$, be the indicator function than:

$$I = \begin{cases} 1, if k = q \\ 0, otherwise \end{cases} \quad (1)$$

Consider the membership value h_i for i^{th} respondent, and the value of the covariates as x_i where the respondents' probability can relate to the membership probability (q) of each latent class. The LCA model can be

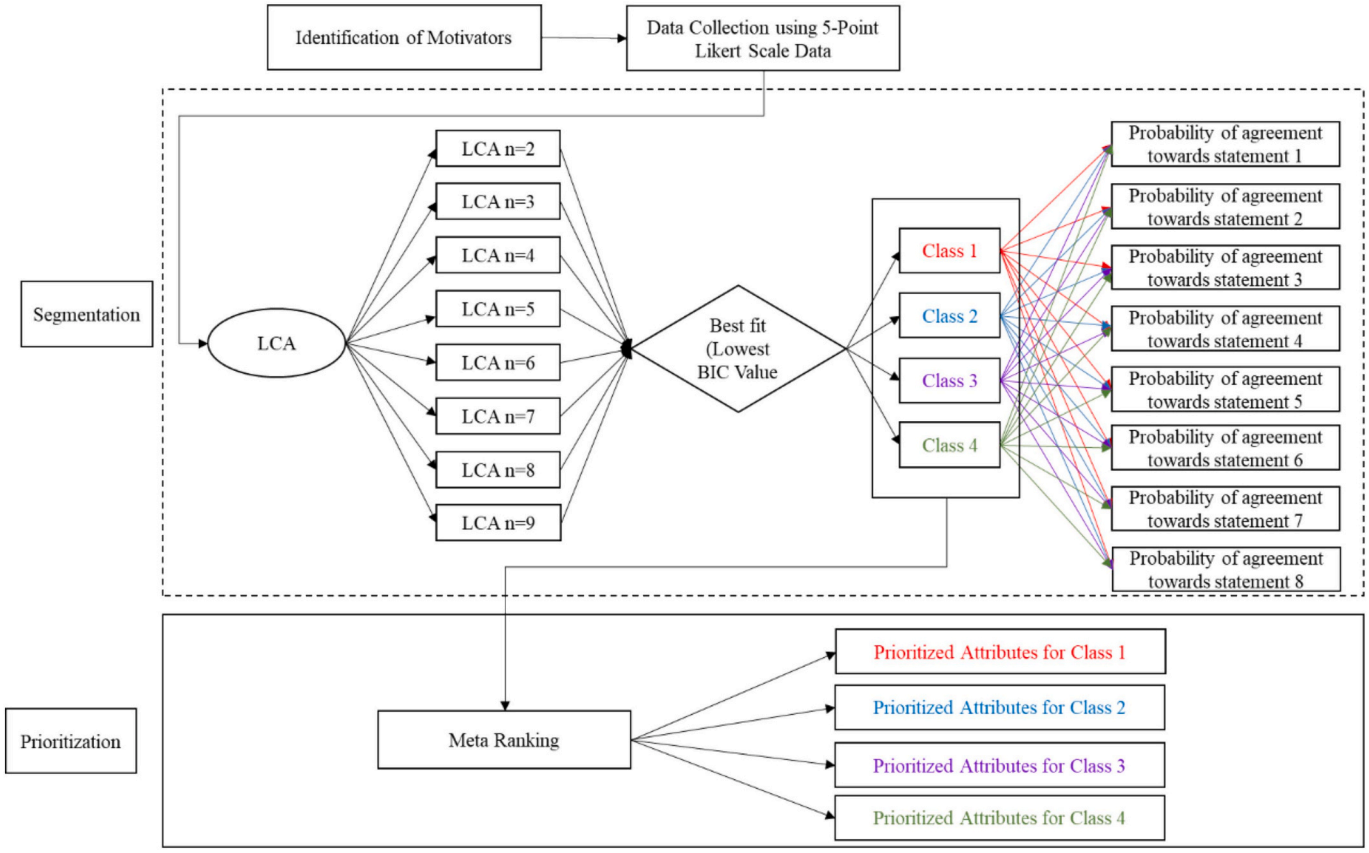

Fig. 2. Methodology framework for identifying commuters' segments and developing ranking.

represented for i^{th} respondent as follows:

$$P(k_i = k) = \sum_{i=1}^{n_l} \beta_i \prod_{y=1}^{Y} \prod_{q=1}^{z_y} \rho_{yk|l}^{I(k_m=q)} \quad (2)$$

where represents the latent class membership probability, and is the statement response probability conditional on latent class probability. The LCA analysis was performed using Jamovi 2.2 software package (Jamovi, 2021). To reduce the risk of convergence to a local maximum, LCA models were estimated using random starting values. The stability of the selected solution was assessed by checking that the final log-likelihood value could be replicated across runs. The local-independence assumption was considered as part of the theoretical specification of the LCA model.

4.2. MCDM techniques for prioritization

Several studies have used various MCDM techniques to rank the attributes using a five-point Likert scale (Abrantes and Wardman, 2011; Patil and Majumdar, 2022; Peng et al., 2011). Using a single MCDM technique for prioritization has certain limitations with respect to the consistency of the rankings (Patil and Majumdar, 2021), and one can use an aggregated prioritized set of rankings to accommodate for such trade-offs (Peng et al., 2011). An analysis of the literature suggests that key studies in mode choice attribute ranking employ a Meta Ranking function (see Fig. 2) to obtain the aggregated rankings (Abrantes and Wardman, 2011). Meta Ranking function internally assesses various MCDM techniques, such as MMOORA (Multi-Objective Optimization by Ratio Analysis), RIM (Reference Ideal Method), TOPSIS (Technique for Order Preference by Similarity to the Ideal Solution), VIKOR (VIseKriterijumska Optimizacija I Kompromisno Resenje) and WASPAS (Weighted Aggregated Sum Product Assessment).

In more detail, this study adopts the Meta Ranking procedure in R using the RankAggreg package (Pihur et al., 2009) which employs an optimization framework to determine the aggregated ranks of perceived benefits based on the scale of the collected data (Likert scale). The input to the aggregation procedure was a rank matrix in which rows corresponded to the eight perceived CP benefits and columns corresponded to the rankings obtained from the individual MCDM methods, namely MMOORA, RIM, TOPSIS, VIKOR, and WASPAS. Separate rank matrices were constructed for each latent class and for the full sample. The RankAggreg function was then used to identify an aggregated ordered list that minimized the distance between the candidate aggregate ranking and the set of method-specific rankings. The aggregation was estimated using the cross-entropy Monte Carlo algorithm, with Spearman footrule distance as the distance measure. Equivalent support for two or more benefits in the input rankings was not resolved through an additional manual rule. Ties were handled within the rank-aggregation optimization procedure, which returned a unique final ordering of perceived benefits for subsequent interpretation. As a robustness check, the aggregated ranking was compared with the rankings produced by the individual MCDM methods. The use of several MCDM methods and their aggregation reduces dependence on any single ranking technique, although no additional sensitivity analysis based on alternative distance measures or aggregation algorithms was conducted.

4.3. Survey and study area

Questionnaire-based face-to-face interviews were conducted to understand commuters' perceptions of CP benefits. The questionnaire was divided into three sections. Section A captures the socio-demographic characteristics of the respondents, while Section B focuses on travel-related characteristics. Section C aims to elicit respondents' consensus

towards various CP-perceived benefits through a five-point Likert scale. Fig. 3 presents the survey technique (Face-to-Face) used for data collection, and the questionnaire used is provided as Appendix A. The CP scenario considered in this study is conceptual and deliberately specified at a general level. Detailed design attributes such as charge levels, spatial configuration, time window, exemptions, enforcement, and revenue allocation were not fixed ex ante. Accordingly, the policy implications derived from the analysis should be interpreted as indicative and preparatory, rather than as directly transferable design recommendations.

Hyderabad, an Indian metropolis, and state capital of Telangana is the case study city where data were collected. Hyderabad is an important political, manufacturing, and commercial centres in India (Patil et al., 2021). Fig. 4 shows the administrative map of Hyderabad, one of India's fastest-growing metropolises, with a population of about 7.7 million (The Census of India, 2011) and a predicted population of almost 19 million by 2041 (GoAP, 2013). Currently, 5.8 million cars traverse the streets of Hyderabad, with 1000 new vehicles being registered daily (Indian Express, 2018). Air quality in Hyderabad has significantly deteriorated due to vehicle exhaust. PM2.5 levels are four times higher (80.6 μg/m3) than the levels of 20 μg/m3. World Health Organization (WHO) considers safe with an air quality index ranging between 151 and 200, indicating unhealthy air quality. As a result, Hyderabad constitutes an ideal candidate city for introducing a CP scheme.

4.4. Database development

The primary motive behind introducing a CP scheme is to minimize private car use and increase the share of public transport modes. The main focus of the current investigation is on individuals who use personal cars for regular travel in Hyderabad.

The data collection was carried out using an on-site intercept survey approach at multiple major trip-generating locations across Hyderabad, including commercial areas, office districts, educational institutions, and transport hubs. A systematic random sampling strategy was adopted, whereby every nth commuter (primarily car users) entering or exiting the selected locations was approached for participation. This method was employed to minimize interviewer bias and ensure a more representative sample. The surveys were conducted during different time periods, including peak and off-peak hours, to capture variations in travel behaviour and traffic conditions. This approach ensured adequate spatial and temporal coverage of diverse commuter groups and trip purposes. Prior to the face-to-face survey, respondents were informed about the purpose of the study, the voluntary nature of their participation, and the intended use of the collected data. Verbal informed consent was obtained from all participants before administering the questionnaire. Respondents were also assured that their responses would remain anonymous and would be used solely for academic research purposes. On average, it took 15 to 18 min to complete each survey. A pen-and-paper face-to-face survey technique was used to administer the questionnaire. The advantage of this technique is that both the interviewer and the respondent are present, allowing the former to guide the respondent through the questionnaire, clarify questions, and reduce the non-response rate per interview attempted, which in our case was 26%. Initially, around 850 car owners were approached during data collection, of whom 588 participated in the survey. Around 153 responses were either incomplete or inconsistent. In some cases, socio-economic details were missing or contradictory. These incomplete and inconsistent responses were eliminated, and 435 complete responses were used to develop the final database. The database was subsequently compared with Hyderabad's population statistics (Government of Telangana, 2021).

5. Results and discussion

This section summarizes the results obtained from the analytical techniques used in the study. Sample descriptive statistics (Table 1) indicate an age distribution of 14% between 18 and 30 years, 37% between 31–40 years, 27% between 41 and 50 years, and around 22% older than 50 years, around 53.5% male and 46.5% female respondents. Around 32% of respondents graduated from high school, 23% had completed intermediate school, 31% had completed a graduate degree, and 14% had completed post-secondary education. The plurality of respondents (45%) had an annual income of up to five lakhs (6042 USD), 27% had an annual income of 5–10 lakhs, and the remaining 28% had an annual income of more than ten lakhs. According to the 2011 census, Hyderabad's socio-demographic profile includes 52% males and roughly 48% females, with about 26% aged 18 to 30, 19% aged 31 to 40, 19% aged 41 to 50, and 17% aged above 50 (The Census of India, 2011). Two possible explanations account for the slight disparity between the sample and the city profile. First, the census data consists of all residents, not only car commuters. Second, a large percentage of the commuters who did not respond were comparatively older commuters (aged more than 50 years) who were less interested in being interviewed by the study team; the study omitted the population under 18 years of age from the study since they cannot legally drive a car. The final sample size of 435 is higher than the minimum sample size of 385 required for an infinite population-based analysis, assuming a 95% confidence level (Taherdoost, 2017).

5.1. Benefit-based segmentation using LCA

LCA is a probabilistic method that estimates the likelihood of various levels of agreement regarding the various benefits of CP in addition to the segmentation. A set of LCA models were developed by varying the number of classes (to) to find the optimum number of classes. Model selection was based on multiple fit indices, including BIC, AIC, and entropy. While AIC values decreased with increasing number of classes, BIC reached its minimum for the 4-class model, indicating the optimal balance between model fit and parsimony. The entropy value for the selected model was 1.000, suggesting excellent classification accuracy. Therefore, the 4-class solution was adopted for further analysis. The BIC, AIC, and entropy values for different estimated LCA models are presented in Table 2. The identified classes were then labelled according to class representation.

The results obtained from the LCA are presented in Table 3. It presents the variable statements and the estimated probabilities of various degrees of agreement or disagreement in the four identified latent

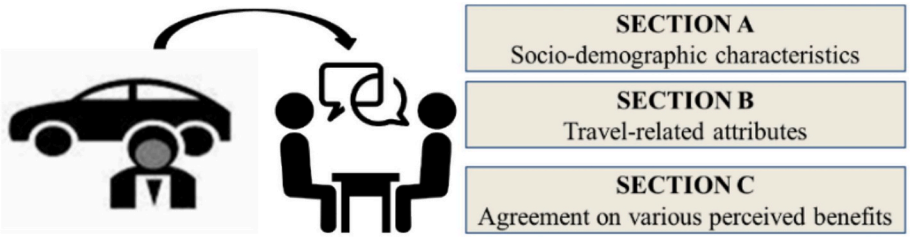

Fig. 3. Survey technique.

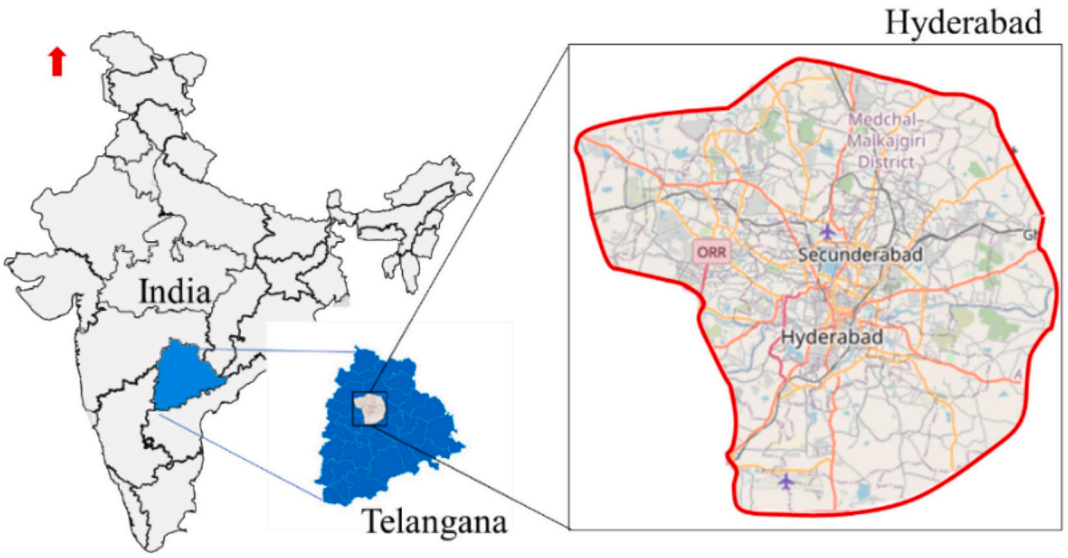

Fig. 4. Study area.

Table 1
Sample descriptive.

Variable	Category	Sample Size	Sample %	Population %
Gender	Male	233	53.5	51.2
	Female	202	46.5	48.8
Age	18–30	111	25.5	34
	31–40	124	28.5	25
	41–50	113	26	18
	≥50	87	20	23
Marital Status*	Married	252	58	53.6
	Unmarried	183	42	46.4
Education	Below Intermediate	231	53	NA
	Graduate or above	204	47	NA
Income	< 5 Lakhs (<6042 USD)	194	45	NA
	≥ 5 Lakhs (≥6042 USD)	241	55	NA
Trip Length	< 20 km	334	77	NA
	>20 km	101	23	NA

NA- Not Available.

Table 2
BIC values of various classes.

Class	BIC value	AIC	Entropy
2	10,850	10,591	0.992
3	10,757	10,332	0.996
4	**10,728**	**10,053**	**1.000**
5	10,752	10,172	0.991
6	10,873	10,177	0.992
7	10,932	**9816**	0.990
8	10,979	9837	0.989
9	11,100	9783	0.997

classes. Perception of respondents in class 1 is more towards travel time-related statements and thus are labelled as Time-saving proponents, while respondents in class 2 are more towards environmental benefits and are labelled as Environmental-pricing proponents. Similarly, class 3 is labelled as safety-pricing proponents, and class 4 is labelled as Social Proponents as the related subsamples show stronger agreement with safety and public transport statements, respectively.

Table 4 presents the socio-demographic characteristics of the different classes. It was found that the majority of the respondents in class C1 (Time-saving proponents) were young (18–30 years of age) and from the lower-middle-income group (0.25–05 million INR), had a daily trip length of fewer than 10 km, which indicates that young lower-income commuters with shorter trip lengths are more concerned about travel time than with other trip-related attributes. Thus, for such commuters promoting travel time reduction and congestion reduction as the scheme's goal can help promote CP. C2 (Environmental-pricing proponents) commuters were aged between 41 and 50 years, and most commuters belong to the higher income group (>1 million INR). Also, the daily trip length for most of the commuters was between 10–20 km, suggesting that Environmental-pricing proponents are high-income elderly commuters with medium daily trip lengths. The sociodemographic profile shows that, C3 class respondents (Safety-pricing proponents) mainly belonged to the age group 31–40 years, whose annual income lies in the range of 0.5 to 1 million INR and a daily trip length of 10–20 Km. C4 (Social proponents) respondents are elderly commuters (age >50 years) with a low and lower-middle annual income (<0.25 million INR and 0.25 – 0.5 million INR) with an average trip length of 10–20 km. Thus, for commuters with such a demographic profile promoting public transport improvement and a shift of departure time to the preferred departure time may increase CP acceptability. The following subsection discusses the results from the MCDM ranking.

5.2. Prioritization of perceived benefits using MCDM techniques

This section presents the results obtained from the RankAggreg function using perception data. Table 5 reports the final aggregated ranks obtained from the rank matrix generated by the five MCDM methods. The values indicate the optimized position of each perceived benefit after rank aggregation, rather than the result of a single prioritization technique. Rankings were estimated separately for the four latent classes and for the full sample. Taken together, the results corroborate the segmentation emerging from the LCA and show that the perceived benefits of CP are far from uniformly distributed across respondents. A first general pattern nonetheless emerges rather clearly: benefits associated with the direct experience of travel tend to occupy the highest positions in the overall ranking, whereas environmental and health-related outcomes, although important for some groups, are generally less salient in the aggregate structure of preferences. At the same time, the class-specific rankings indicate that this aggregate pattern masks substantial internal variation, with each segment attaching a different configuration of importance to the expected effects of CP.

Travel-time minimization emerges as the most salient result in the

Table 3
Response probabilities of latent classes to various perceived benefits of CP.

	C-1 Time-saving Proponents	C-2 Environmental-pricing Proponents	C-3 Safety-pricing Proponents	C-4 Social Proponents
Cluster Size (n)	0.350 (152)	0.189 (82)	0.218 (95)	0.243 (106)
Alt_1 Implementing CP will help in accident reduction (ACC_RDC)				
Strongly Disagree	0.218	0.382	0.156	0.195
Disagree	0.244	0.240	0.083	0.125
Neutral	0.263	0.228	0.000	0.106
Agree	0.104	0.150	0.508	0.224
Strongly Agree	0.171	0.000	0.253	0.350
Alt_2 Implementing CP will improve public transport (PT_IMP)				
Strongly Disagree	0.210	0.239	0.138	0.073
Disagree	0.333	0.192	0.166	0.072
Neutral	0.094	0.176	0.175	0.185
Agree	0.136	0.132	0.293	0.395
Strongly Agree	0.226	0.261	0.227	0.275
Alt_3 Implementing CP will promote Active transportation (Cycling, Walking) (AC_Mode)				
Strongly Disagree	0.249	0.216	0.107	0.153
Disagree	0.249	0.114	0.275	0.259
Neutral	0.234	0.191	0.235	0.286
Agree	0.208	0.361	0.257	0.175
Strongly Agree	0.060	0.117	0.125	0.127
Alt_4 Implementing CP will improve road safety (RS_IMP)				
Strongly Disagree	0.220	0.216	0.100	0.163
Disagree	0.266	0.156	0.079	0.124
Neutral	0.175	0.228	0.225	0.277
Agree	0.165	0.199	0.400	0.232
Strongly Agree	0.174	0.201	0.196	0.203
Alt_5 Implementing CP will reduce congestion (CON_RDC)				
Strongly Disagree	0.210	0.264	0.136	0.106
Disagree	0.212	0.166	0.105	0.192
Neutral	0.081	0.180	0.094	0.134
Agree	0.293	0.159	0.400	0.292
Strongly Agree	0.204	0.230	0.264	0.275
Alt_6 Implementing CP will change departure time to preferred departure time (SFT_DT)				
Strongly Disagree	0.213	0.287	0.143	0.164
Disagree	0.175	0.238	0.046	0.098
Neutral	0.263	0.228	0.000	0.106
Agree	0.158	0.230	0.421	0.199
Strongly Agree	0.191	0.016	0.389	0.432
Alt_7 Implementing CP will reduce travel time (TT_RDN)				
Strongly Disagree	0.078	0.000	0.645	0.000
Disagree	0.000	0.213	0.000	0.784
Neutral	0.213	0.417	0.343	0.000
Agree	0.708	0.119	0.011	<0.001
Strongly Agree	<0.001	0.250	0.000	0.215
Alt_8 Implementing CP will improve the environmental condition (ENV_IMP)				
Strongly Disagree	0.105	0.000	0.654	0.000
Disagree	0.000	0.000	0.000	0.785
Neutral	0.330	<0.001	0.345	0.000
Agree	0.564	0.013	<0.001	<0.001
Strongly Agree	<0.001	0.987	0.000	0.215

entire ranking structure. It ranks first in the overall sample, as well as in C1 and C4, and second in C3, while only C2 assigns it a less prominent role, placing it fifth. This makes travel-time reduction the most widely shared perceived benefit of CP across the sample, suggesting that respondents primarily assess the scheme in terms of its ability to improve day-to-day travel conditions. This finding is consistent with Bhatt et al. (2008) and Haustein et al. (2018), who identify travel-time minimization as a key determinant of CP acceptability. It is also coherent with evidence showing that reductions in congestion and travel time following CP implementation contributed to greater acceptance in both London and Stockholm (Schuitema et al., 2010; Vonk Noordegraaf et al., 2014). The class-specific probabilities reinforce this interpretation. In C1, for example, travel-time minimization reaches an agreement probability of 71% and combines with the relatively high position assigned to congestion reduction, confirming a strong orientation toward immediate trip-efficiency gains. In practical terms, these results suggest that promoting CP through its direct effects on travel time may be especially effective in increasing its acceptability.

Congestion reduction presents a related, though not identical, pattern. In the overall sample it ranks third, behind travel-time minimization and public transport improvement, which confirms that it is perceived as one of the major expected benefits of CP. However, its

Table 4
Sociodemographic characteristics of different classes.

		C-1 Time-saving proponents %	C-2 Environmental-pricing proponents %	C-3 Safety-pricing proponents %	C-4 Social proponents %	Overall sample
		35(152)	19 (82)	22 (95)	24 (106)	(435)
Age	18–30	36(54)	13 (11)	21 (20)	17 (18)	103
	31–40	23 (35)	21 (17)	46 (44)	26 (28)	124
	41–50	27 (41)	38 (31)	17 (16)	24 (25)	113
	>50	14 (22)	28 (23)	16(15)	33 (35)	95
Income (million INR)	<0.25	14 (22)	15 (12)	29 (28)	35 (37)	99
	0.25–0.5	36 (54)	30 (25)	24 (23)	30 (32)	134
	0.5–1	28 (42)	12 (10)	33 (31)	21 (22)	105
	>1	22 (34)	43 (35)	14 (13)	14 (15)	97
Trip Length (Km)	<10	41 (63)	27 (22)	25 (24)	33 (35)	144
	10–20	38 (58)	52 (43)	44 (42)	45 (48)	191
	>20	20 (31)	21 (17)	31 (29)	22 (23)	100

Note: Number of respondents in brackets (−).

Table 5
Rankings of the perceived benefits of different MCDM techniques.

Attributes	C-1 Time-saving proponents	C-2 Environmental-pricing proponents	C-3 Safety-pricing proponents	C-4 Social proponents	Overall sample
Crash reduction	5	8	1	7	7
Active mode promotion	7	3	8	8	8
Travel-time minimization	1	5	2	1	1
Improvement of public transport	4	2	5	2	2
Environment quality improvement	8	1	7	6	6
Road safety improvement	6	7	3	4	5
Congestion reduction	2	4	4	5	3
Departure time flexibility	3	6	6	3	4

importance varies across classes: it is ranked second in C1, fourth in both C2 and C3, and fifth in C4. Unlike travel-time minimization, congestion reduction therefore appears to operate as a broadly recognized but not always dominant benefit. This result is in line with Daniel and Bekka (2000), who report congestion reduction as one of the most important benefits associated with CP and one that tends to weigh more than environmental outcomes. The probabilities derived from the LCA add further nuance, showing that agreement is highest in C3, at about 66%, and remains substantial in C1, at around 50%. Thus, although congestion reduction is not uniformly prioritized across the classes, it still contributes significantly to the perceived attractiveness of the scheme and remains one of the most policy-relevant benefits in the full sample.

Public transport improvement occupies a particularly interesting position because it is one of the few benefits showing relatively broad relevance across classes. It ranks second in the overall sample and is also placed second in both C2 and C4, while C1 and C3 rank it fourth and fifth, respectively. This indicates that improvement of public transport is not limited to a specific segment, but is instead perceived as one of the most credible and widely valued expected outcomes of CP. The result is coherent with Santos and Fraser (2006), who highlight the important role played by public transport in the successful implementation of CP in London and Singapore, also noting that improved reliability of public transport contributed to the success of the London scheme. The associated probabilities support this interpretation: agreement is about 39% in C2, 52% in C3, and 66% in C4. Especially in C4, the importance assigned to public transport improvement, together with travel-time minimization and departure time flexibility, helps explain the internal consistency of the class profile. More broadly, the strong ranking of this benefit in the overall sample suggests that collective transport improvements are perceived not as a secondary by-product of CP, but as one of the central conditions under which the scheme becomes acceptable.

Departure time flexibility occupies a more intermediate position, but still plays a meaningful role in the benefit structure. It ranks fourth in the overall sample, third in both C1 and C4, and sixth in C2 and C3. This uneven distribution suggests that the possibility of travelling closer to one's preferred departure time is especially valued by segments more concerned with trip organization, timing, and reliability, whereas it is less central for those oriented toward environmental or safety considerations. The finding is aligned with Marazi et al. (2022), who show that departure time influences route choice and travel behaviour under CP, and also with Li et al. (2010) and Yamamoto et al. (2000), who report that departure time affects both travel-time savings and travel-time variability. The highest agreement probability is found in C4, where it reaches about 63%, indicating that this benefit is particularly meaningful for respondents who evaluate CP in relation to broader coordination and service-related gains.

A different configuration emerges for safety-related outcomes, which reveal a much sharper segmentation pattern. Crash reduction is ranked first in C3, but only fifth in C1, eighth in C2, and seventh in C4; in the overall sample it ranks seventh. Road safety improvement follows a somewhat similar, though less polarized, pattern: it ranks third in C3, fourth in C4, fifth in the full sample, and much lower in C1 and C2. These results indicate that safety-related concerns are not especially prominent in the aggregate ranking, yet they become central for particular segments. C3, in particular, is clearly distinguished by its strong safety orientation. The probability of agreement with crash reduction reaches about 75% in this class, while road safety improvement attains about 59%. This confirms that, for C3, CP is interpreted primarily as a policy instrument capable of improving safety conditions and reducing crash-related externalities. This result is consistent with Zhong et al. (2017), who report that optimal road charging can help reduce congestion-related externalities such as the number of crashes. At the same time, the low position assigned to crash reduction in C2 and its weak ranking in the overall sample show that safety is not among the leading evaluative criteria for most respondents. What matters here is therefore not whether safety is a potential benefit of CP, but rather that its salience is highly differentiated across commuter groups.

The environmental dimension displays an almost opposite pattern. Environment quality improvement is ranked first in C2, but eighth in C1, seventh in C3, sixth in C4, and sixth in the overall sample. Few results

illustrate preference heterogeneity more clearly than this one. For the full sample, environmental quality remains secondary when compared with more immediate travel-related benefits. For C2, however, it is by far the defining benefit, with an agreement probability of 98%, the highest among all benefit-class combinations. This suggests that C2 interprets CP primarily as an environmental policy rather than as a measure aimed at improving travel efficiency. The same orientation, though less strongly, is reflected in active mode promotion. In the overall sample, active mode promotion ranks last; it is also placed seventh in C1 and eighth in both C3 and C4. Only C2 assigns it a relatively high position, ranking it third. The agreement probability in C2 is about 36%, indicating a distinct, though not overwhelming, openness to the role of CP in encouraging cycling and walking. These findings are in line with Marazi et al. (2022), who also report that active commuting modes can represent a relevant benefit of CP in congested urban settings. At the same time, the weak ranking of both environmental improvement and active mode promotion outside C2 indicates that sustainability-related outcomes are not the principal drivers of support for CP in the broader commuter population.

Across the full sample, the results indicate that commuters attach greatest importance to benefits directly affecting everyday travel conditions, with travel-time minimization, improvement of public transport, and congestion reduction ranking first, second, and third, respectively. This suggests that, at an aggregate level, support for congestion pricing is more likely to be associated with tangible and immediately experienced gains in mobility performance than with broader environmental or health-related outcomes. At the same time, the class-specific rankings reveal substantial heterogeneity behind this overall pattern. Time-saving proponents (C1) and Social proponents (C4) strongly prioritize travel-time minimization, while Environmental-pricing proponents (C2) place clear emphasis on environmental quality improvement and, to a lesser extent, active mode promotion. Safety-pricing proponents (C3) differ markedly from the other groups in assigning highest priority to crash reduction and relatively high importance to road safety improvement. Improvement of public transport emerges as one of the most consistently valued benefits across classes, ranking particularly high for C2 and C4 and remaining relevant, though less central, for the other groups. By contrast, active mode promotion and environmental improvement receive limited support in the overall sample, but become highly salient within the environmentally oriented segment, showing that benefits with weak aggregate salience may still be decisive for specific commuter groups. Overall, the findings show that the aggregate ranking captures only part of the picture: while the whole sample points to a general preference for practical mobility-related benefits, the class-level results demonstrate that different commuter segments interpret the value of congestion pricing through distinct benefit bundles. This confirms that any attempt to design, communicate, or implement CP as a uniform policy is likely to overlook relevant differences in user expectations and may therefore be less effective than a more segmented and benefit-sensitive approach.

6. Policy implications

The policy implications emerging from this study point to the need for a more operationally differentiated approach to the prospective implementation of CP in rapidly growing urban contexts such as Hyderabad. Rather than treating commuters as a homogeneous population, the results suggest that implementation strategies should be designed around the heterogeneous benefits that different user groups associate with CP. This implies that policy design, communication, accompanying measures, and revenue allocation should be aligned with the expectations of the main latent commuter segments identified in the analysis.

The identification of four commuter classes provides a practical basis for formulating application-oriented policy measures.

For Time-Saving Proponents (Class C1), who attach primary importance to travel-time reduction and congestion relief, CP should first be introduced in corridors and time periods where congestion is recurrent, measurable, and particularly visible, such as peak-hour access to central business districts and major employment areas. In operational terms, a pilot scheme could initially apply only on weekdays during the morning and evening peaks, with tariff levels calibrated to produce modest but observable demand reductions. To make the benefits immediately visible, the scheme should be accompanied by corridor-specific monitoring of average speeds, travel times, and trip reliability before and after implementation. These results should be communicated through variable message signs, mobile applications, and regular public reporting. In this way, the principal benefit valued by this group would not remain an abstract policy claim but would be translated into an observable performance outcome.

For Environmental-Pricing Proponents (Class C2), who prioritize environmental quality and, to a lesser extent, active mobility, implementation should be explicitly linked to visible environmental co-benefits. In practical terms, part of the revenues generated through CP should be earmarked for clearly identifiable interventions within or near the charging area, such as air-quality monitoring stations, roadside greening, improvement of sidewalks, and the provision of protected cycling infrastructure on feeder corridors. In addition, the authority implementing CP should publish periodic indicators on emissions, local air quality, and traffic volumes in order to demonstrate whether environmental improvements are materializing over time. Linking CP revenues to specific, place-based environmental improvements may strengthen policy credibility and reduce the perception of CP as a purely revenue-raising instrument (Abulibdeh et al., 2015; Clements et al., 2021).

With respect to Safety-Pricing Proponents (Class C3), who assign greater importance to crash reduction and road safety, revenues should be visibly reinvested in safety-oriented interventions within the charging zone and adjacent corridors. These could include signalized pedestrian crossings, junction redesign, traffic calming near schools and commercial districts, lane discipline measures, and selective deployment of intelligent transport systems for speed and traffic monitoring. Here too, implementation should be accompanied by measurable indicators, such as changes in crash frequency, pedestrian conflicts, and average vehicle speeds, so that safety improvements can be documented and periodically communicated. This is especially important because safety is more likely to support acceptability when users can directly observe the link between the charging scheme and tangible improvements in road conditions.

When focusing on Social Proponents (Class C4), who place stronger emphasis on public transport improvement and broader collective benefits, CP implementation should be clearly integrated with a package of public transport enhancement measures. In the Indian context, this means that a pilot scheme should not be introduced as a stand-alone pricing intervention, but together with service improvements in the affected corridor, such as higher bus frequencies during charging periods, more reliable schedules, better interchange facilities, improved last-mile connections, and where feasible, dedicated bus priority measures. For lower-income or more vulnerable groups, accompanying measures may include targeted fare discounts, integrated ticketing options, or exemptions and compensatory mechanisms where justified. Such measures are important not only from an equity perspective, but also because they signal that CP is intended to improve accessibility rather than merely restrict car use.

More generally, the study suggests that CP in Indian cities should follow a phased and test-based implementation strategy rather than a full-scale immediate rollout. A first phase could consist of a limited pilot in one highly congested corridor or central zone, restricted to peak hours and supported by temporary or semi-permanent enforcement technology such as Automatic Number Plate Recognition (ANPR), digital permits, or geo-fenced payment systems. A second phase could expand the charging window, the geographic coverage, or the tariff differentiation

only after the first phase has been evaluated against predefined indicators. Such an incremental approach would make implementation more manageable administratively, reduce political risk, and allow learning before citywide scaling.

A central practical issue concerns revenue use and institutional credibility. The results of this study suggest that revenue allocation should not remain generic. Instead, a formal revenue-use framework should be defined ex ante and communicated before implementation. This framework should identify a limited number of expenditure categories directly linked to the benefits most valued by commuters, namely public transport improvements, road safety measures, walking and cycling infrastructure, and selected environmental interventions. In institutional terms, one option would be to establish a ring-fenced urban mobility improvement fund, subject to periodic public reporting. This would increase transparency and may reduce opposition rooted in distrust over the final use of collected revenues, a concern already emphasized in the literature on CP acceptability and policy design (de Oliveira et al., 2019; Schade and Baum, 2007; Marcucci et al., 2005).

Findings also suggest that communication and public engagement should be embedded in implementation, rather than treated as an ex post complement. In practical terms, this means that before introducing CP, authorities should organize a structured process including stakeholder consultations, public information campaigns, and corridor-level demonstrations. Communication should not rely on a single generic message. Rather, it should differentiate the arguments according to the main expected benefits: travel-time reliability for C1, environmental gains for C2, safety improvements for C3, and public transport enhancement for C4. In addition, publishing baseline conditions and ex-post performance metrics for the pilot area would help transform the policy debate from abstract opposition to evidence-based assessment. This is consistent with the broader view that participation and sense-making are important preconditions for the acceptance of transport pricing policies (Torrance and Froese, 2011).

CP implementation in India seems more likely to be acceptable and effective when designed as a benefit-linked policy package rather than as an isolated pricing instrument. The main implication is therefore not simply that different commuter groups value different outcomes, but that these differences can be used to structure concrete policy choices regarding where to introduce CP first, how to phase it, which accompanying measures to prioritize, how to allocate revenues, and how to communicate expected benefits. In this respect, the segmentation and prioritization approach adopted in the paper provides an empirical basis for moving from general support for CP to more context-specific and implementable policy design. This conclusion is also coherent with previous studies emphasizing the importance of attitudinal heterogeneity and market segmentation in transport policy analysis (Pani et al., 2019; Patil and Majumdar, 2021).

7. Conclusion

This paper starts from a clear problem: although congestion pricing is widely recognized as a potentially effective instrument for addressing urban congestion, its implementation remains difficult in contexts where policymakers have not yet introduced the policy and where public perceptions remain unformed or weakly structured. In this respect, the study addresses a specific gap in the literature, namely the limited attention devoted to the ex-ante perception of CP benefits in a pre-implementation setting, especially in a rapidly growing Indian metropolitan context. More specifically, the paper examines whether distinct latent commuter segments can be identified on the basis of perceived CP benefits and whether those benefits can then be prioritized across segments in ways useful for the early design of participatory and context-sensitive CP strategies.

To address these questions, the study adopts an attitudinal and segmentation-based approach, combining face-to-face survey data from car commuters in Hyderabad with LCA and Meta Ranking. This methodological choice is consistent with the paper's objective: not to evaluate responses to a fully specified operational CP scheme, but to identify how different groups interpret the expected value of congestion pricing before implementation. In this sense, the paper contributes less by forecasting behavioural responses to a predefined policy design than by reconstructing the structure of perceived benefits that may condition acceptability, credibility, and early policy support.

The results show that, at the aggregate level, commuters primarily value CP for its direct mobility-related benefits, especially travel-time minimization, improvement of public transport, and congestion reduction. At the same time, the class-level analysis shows that this aggregate ordering conceals substantial heterogeneity. C1 is mainly oriented toward immediate travel-efficiency gains; C2 attributes greatest importance to environmental quality improvement and, secondarily, active mode promotion; C3 is clearly characterized by safety-related concerns, particularly crash reduction; and C4 combines strong support for travel-time minimization with a marked preference for public transport improvement and departure-time flexibility. The paper thus shows that commuters do not organize the perceived value of CP around a single dominant evaluative logic, but around differentiated benefit bundles that vary across commuter groups.

This finding has two main implications. First, it reinforces the argument that ex-ante public perceptions matter not because congestion pricing is a voluntary measure, but since political feasibility, legitimacy, and implementation credibility depend in part on whether commuters perceive the expected benefits of the policy as relevant and plausible. Second, it suggests that CP is more likely to gain support when policymakers present it not as an abstract pricing instrument, but as a benefit-linked policy package whose communication, accompanying measures, and revenue-use priorities align with the concerns of different user groups. In this respect, the policy discussion developed in the paper follows directly from the empirical results: phased introduction, visible reinvestment, differentiated communication, and early participation are not generic recommendations, but operational consequences of the heterogeneous preference structure observed in the data.

The study also has some limitations. The analysis is based on car commuters only, focuses on a single city, and examines a conceptual rather than fully specified CP scenario. In addition, the adopted methods entail the usual assumptions associated with latent class modelling and rank aggregation. These limitations do not invalidate the contribution of the paper, but they do define its scope: the findings should be interpreted as analytically informative and policy-relevant for a pre-implementation stage, rather than as directly transferable design prescriptions for all Indian cities or all user groups. Accordingly, future research should extend the analysis to additional user categories, compare different urban contexts, conduct formal local-independence diagnostics (e.g., bivariate residual checks), and test alternative CP designs with more explicit specification of pricing levels, spatial boundaries, exemptions, enforcement, and revenue-use arrangements.

Overall, the paper adds value by showing that the first challenge of congestion pricing in cities such as Hyderabad lies not only in technical design, but also in the prior identification of which benefits are likely to make the policy intelligible, credible, and acceptable to different segments of the affected population. In this sense, the study argues that heterogeneity in perceived benefits is not a secondary complication to be managed after design, but one of the central conditions that should shape design from the outset. For congestion pricing in India, the ex-ante phase is not a preliminary technicality but, to borrow Aristotle, "the beginning is more than half of the whole".

CRediT authorship contribution statement

Naveed Farooz Marazi: Writing – original draft, Visualization, Validation, Methodology, Investigation, Data curation, Formal analysis. **Bandhan Bandhu Majumdar:** Writing – review & editing, Visualization, Validation, Supervision, Software, Resources, Methodology,

Investigation, Conceptualization. **Prasanta K. Sahu:** Writing – review & editing, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Conceptualization. **Edoardo Marcucci:** Writing – review & editing, Visualization, Investigation. **Valerio Gatta:** Writing – review & editing, Visualization, Investigation.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.cstp.2026.101904.

References

Aaron O'Neill, 2020. India Degree of urbanization from 2010 to 2020 [WWW Document]. Statista. URL https://www.statista.com/statistics/271312/urbanization-in-india/ (accessed 7.3.21).

Abrantes, P.A.L., Wardman, M.R., 2011. Meta-analysis of UK values of travel time: an update. Transp. Res. Part A Policy Pract. 45, 1–17. https://doi.org/10.1016/j.tra.2010.08.003.

Abulibdeh, A., Andrey, J., Melnik, M., 2015. Insights into the fairness of cordon pricing based on origin-destination data. J. Transp. Geogr. 49, 61–67. https://doi.org/10.1016/j.jtrangeo.2015.10.014.

Anas, A., 2020. The cost of congestion and the benefits of congestion pricing: A general equilibrium analysis☆. Transp. Res. Part B 136, 110–137. https://doi.org/10.1016/j.trb.2020.03.003.

Attard, M., Enoch, M., 2011. Policy transfer and the introduction of road pricing in Valletta. Malta. Transp. Policy 18, 544–553. https://doi.org/10.1016/j.tranpol.2010.10.004.

Balwani, A., Singh, S., 2009. Network impacts of distance-based road user charging. NETNOMICS Econ. Res. Electron. Netw. 10, 53–75.

Behruz, H., Safaie, A., Chavoshy, A.P., 2012. Tehran traffic congestion charging management: a success story. WIT Trans. Built Environ. 128, 445–456. https://doi.org/10.2495/UT120381.

Bhat, C.R., 1997. An endogenous segmentation mode choice model with an application to intercity travel. Transp. Sci. 31, 34–48.

Bhatt, K., Higgins, T., Berg, J., 2008. Lessons learned from international experience in congestion pricing. U.S. Dep. Transp. Fed. Highw Adm. 85.

Brown, V., Moodie, M., Carter, R., 2015. Congestion pricing and active transport - evidence from five opportunities for natural experiment. J. Transp. Heal. 2, 568–579. https://doi.org/10.1016/j.jth.2015.08.002.

Clements, L.M., Kockelman, K.M., Alexander, W., 2021. Technologies for congestion pricing. Res. Transp. Econ. 90, 100863. https://doi.org/10.1016/j.retrec.2020.100863.

Daniel, J.I., Bekka, K., 2000. The environmental impact of highway congestion pricing. J. Urban Econ. 47, 180–215. https://doi.org/10.1006/juec.1999.2135.

Danielis, R., Rotaris, L., Marcucci, E., Massiani, J., 2012. A medium term evaluation of the Ecopass road pricing scheme in Milan: economic, environmental and transport impacts. In: Economics and Policy of Energy and the Environment, pp. 49–83. https://doi.org/10.3280/EFE2012-002004.

Dash, D.K., 2018. Metro Cities Waste Rs 1.5 Lakh Crore Per Year Due To Traffic Congestion, Kolkata Tops The List [WWW Document]. india times. URL https://www.indiatimes.com/news/india/traffic-congestion-costs-four-major-indian-cities-rs-1-5-lakh-crore-a-year-344216.html (accessed 11.25.20).

Devaraj, A., Ambi Ramakrishnan, G., Nair, G.S., Srinivasan, K.K., Bhat, C.R., Pinjari, A. R., Ramadurai, G., Pendyala, R.M., 2020. Joint model of application-based ride hailing adoption, intensity of use, and intermediate public transport consideration among workers in Chennai city. Transp. Res. Rec. 2674, 152–164. https://doi.org/10.1177/0361198120912237.

Geng, K., Wang, Y., Ettema, D., Anderson, J.R., 2021. Exploring the effects of congestion charge on relocation decisions under non-capital functions relieving strategy in Beijing. Res. Transp. Bus. Manag. 38, 100469. https://doi.org/10.1016/j.rtbm.2020.100469.

GoAP, 2013. Approval of metropolitan development plan-2031 for Hyderabad metropolitan region.

Government of Telangana, 2021. Telangana Socio Economic Outlook 2021. Plan. Dep. Gov. Telangana 1–303.

Haustein, S., Thorhauge, M., Cherchi, E., 2018. Commuters' attitudes and norms related to travel time and punctuality: a psychographic segmentation to reduce congestion. Travel Behav. Soc. 12, 41–50. https://doi.org/10.1016/j.tbs.2018.04.001.

Hensher, D.A., Li, Z., 2013. Referendum voting in road pricing reform: a review of the evidence. Transp. Policy 25, 186–197. https://doi.org/10.1016/j.tranpol.2012.11.012.

Indian Express, 2018. Hyderabad commuters spend three minutes per km [WWW Document]. URL https://www.newindianexpress.com/cities/hyderabad/2018/may/05/hyderabad-commuters-spend-three-minutes-per-km-1810315.html (accessed 3.21.21).

Jaensirisak, S., Wardman, M., May, A.D., 2005. Explaining variations in public acceptability of road pricing schemes. J. Transp. Econ. Policy 39, 127–153.

Jamovi, 2021. The jamovi project (2021). jamovi. (Version 2.2).

Junge, J., Levinson, D., 2013. Property tax on privatized roads. Res. Transp. Bus. Manag. Mak. 7, 35–42. https://doi.org/10.1016/j.rtbm.2013.03.010.

Li, Z., Hensher, D.A., Rose, J.M., 2010. Willingness to pay for travel time reliability in passenger transport: a review and some new empirical evidence. Transp. Res. Part E Logist. Transp. Rev. 46, 384–403. https://doi.org/10.1016/j.tre.2009.12.005.

Marazi, N.F., Majumdar, B.B., Sahu, P.K., 2024. Examining congestion pricing scheme effectiveness using the travel time congestion index. Transp. Res. Rec. https://doi.org/10.1177/03611981241242061.

Marazi, N.F., Majumdar, B.B., Sahu, P.K., Panda, S., Koramati, S., 2023. Traffic congestion assessment tool for urban roads based on traffic and geometric characteristics: a case of Hyderabad India. ASCE Part A Syst. https://doi.org/10.1061/JTEPBS.TEENG-7908.

Marazi, N.F., Majumdar, B.B., Sahu, P.K., Potoglou, D., 2022. Congestion pricing acceptability among commuters: an Indian perspective. Res. Transp. Econ. 95, 101180. https://doi.org/10.1016/j.retrec.2022.101180.

Marazi, N.F., Sahu, P.K., Majumdar, B.B., Pani, A., 2026. Is hybrid measure an effective instrument for behavioural modal shift decisions to mitigate traffic congestion. Res. Transp. Bus. Manag. 66, 101608. https://doi.org/10.1016/j.rtbm.2026.101608.

Marcucci, E., Marini, M., 2003. Individual uncertainty and the political acceptability of road pricing policies. In: Acceptability of Transport Pricing Strategies. Emerald Group Publishing Limited, pp. 279–296.

Marcucci, E., Marini, M., Ticchi, D., 2005. Road pricing as a citizen-candidate game. Eur. Transp. 31, 28–45.

Marcucci, E., Site, P.D., Gatta, V., Pompetti, P., 2018. Ex-ante acceptability of road pricing and modal shift estimation: the case of Rome. Sci. Reg. 477–504. https://doi.org/10.14650/90990.

Marcucci, E., 2001. Road pricing: old beliefs, present awareness and future research paths. Int. J. Transp. Econ. / Riv. Internazionale Di Econ. Dei Trasp. 28, 49–80.

Meng, Q., Liu, Z., 2012. Impact analysis of cordon-based congestion pricing on mode-split for a bimodal transportation network. Transp. Res. Part C Emerg. Technol. 21, 134–147. https://doi.org/10.1016/j.trc.2011.06.007.

Mohammadi, M., Rezaei, J., 2020. Ensemble ranking: aggregation of rankings produced by different multi-criteria decision-making methods. Omega 96, 102254.

Moradpour, S., Long, S., 2019. Using combined multi-criteria decision-making and data mining methods for work zone safety: a case analysis. Case Stud. Transp. Policy 7, 178–184. https://doi.org/10.1016/j.cstp.2019.04.008.

MOSP, G., 2018. Motor vehicles- Statistical yearbook India 2018 [WWW Document]. GOI. URL Government of India, Motor vehicles- Statistical yearbook India., 2018). (accessed 11.25.20).

Nikitas, A., Avineri, E., Parkhurst, G., 2018. Understanding the public acceptability of road pricing and the roles of older age, social norms, pro-social values and trust for urban policy-making: the case of Bristol. Cities 79, 78–91. https://doi.org/10.1016/j.cities.2018.02.024.

Oakil, A.T.M., Nijland, L., Dijst, M., 2016. Rush hour commuting in the Netherlands: gender-specific household activities and personal attitudes towards responsibility sharing. Travel Behav. Soc. 4, 79–87. https://doi.org/10.1016/j.tbs.2015.10.003.

de Oliveira, L.K., Souza, S.L., Cardoso, L., Bessa Junior, J.E., de Oliveira, R.L.M., dos Bracarense, L.S.F.P., 2019. Is congestion pricing an urban mobility solution to Brazilian cities? J. Urban Environ. Eng. 13 (2), 302–316.

Pani, A., Sahu, P.K., Majumdar, B.B., 2019. Expenditure-based segmentation of freight travel markets: identifying the determinants of freight transport expenditure for developing marketing strategies. Res. Trans. Business & Manag. 33, 100425.

Pani, A., Mishra, S., Golias, M., Figliozzi, M., 2020. Evaluating public acceptance of autonomous delivery robots during COVID-19 pandemic. Transp. Res. Part D Transp. Environ. 89, 102600. https://doi.org/10.1016/j.trd.2020.102600.

Parry, I.W.H., 2009. Pricing urban congestion. Annu. Rev. Resour. Econ. 1, 461–484. https://doi.org/10.1146/annurev.resource.050708.144226.

Patil, M., Majumdar, B.B., 2022. An investigation on the key determinants influencing electric two-wheeler usage in urban Indian context. Res. Transp. Bus. Manag. 43, 100693. https://doi.org/10.1016/j.rtbm.2021.100693.

Patil, M., Majumdar, B.B., 2021. Prioritizing key attributes influencing electric two-wheeler usage: a multi criteria decision making (MCDM) approach – a case study of

Hyderabad. India. Case Stud. Transp. Policy 9, 913–929. https://doi.org/10.1016/j.cstp.2021.04.011.
Patil, M., Majumdar, B.B., Sahu, P.K., Truong, L.T., 2021. Evaluation of prospective users' choice decision toward electric two-wheelers using a stated preference survey: an Indian perspective. Sustain. 13. https://doi.org/10.3390/su13063035.
Peng, Y., Kou, G., Wang, G., Shi, Y., 2011. FAMCDM: a fusion approach of MCDM methods to rank multiclass classification algorithms. Omega 39, 677–689. https://doi.org/10.1016/j.omega.2011.01.009.
Percoco, M., 2021. A formal test of the long-term environmental effects of road pricing in Milan. Res. Transp. Econ. 85, 100951. https://doi.org/10.1016/j.retrec.2020.100951.
Phang, S.Y., Toh, R.S., 2004. Road congestion pricing in Singapore: 1975 to 2003. Transp. J. 43, 16–25.
Pihur, V., Datta, S., Datta, S., 2009. RankAggreg, an R package for weighted rank aggregation. BMC Bioinformatics 10, 62. https://doi.org/10.1186/1471-2105-10-62.
Rivasplata, C.R., 2013. Congestion pricing for Latin America: prospects and constraints. Res. Transp. Econ. 40, 56–65. https://doi.org/10.1016/j.retrec.2012.06.037.
Rotaris, L., Danielis, R., Marcucci, E., Massiani, J., 2010. The urban road pricing scheme to curb pollution in Milan, Italy: description, impacts and preliminary cost-benefit analysis assessment. Transp. Res. Part A: Policy Practice 44 (5), 359–375.
Santos, G., 2005. Urban congestion charging: a comparison between London and Singapore. Transp. Rev. 25, 511–534. https://doi.org/10.1080/01441640500064439.
Santos, G., Fraser, G., 2006. Road pricing. Economist (Leiden). 116, 545–560. https://doi.org/10.1007/BF02367282.
Schade, J., Baum, M., 2007. Reactance or acceptance? Reactions towards the introduction of road pricing. Transp. Res. Part A Policy Pract. 41, 41–48. https://doi.org/10.1016/j.tra.2006.05.008.
Schade, J., Schlag, B., 2003. Acceptability of urban transport pricing strategies. Transp. Res. Part F Traffic Psychol. Behav. 6, 45–61. https://doi.org/10.1016/S1369-8478(02)00046-3.
Schaller, B., 2010. New York City's congestion pricing experience and implications for road pricing acceptance in the United States. Transp. Policy 17, 266–273. https://doi.org/10.1016/j.tranpol.2010.01.013.
Schuitema, G., Steg, L., Forward, S., 2010. Explaining differences in acceptability before and acceptance after the implementation of a congestion charge in Stockholm. Transp. Res. Part A Policy Pract. 44, 99–109. https://doi.org/10.1016/j.tra.2009.11.005.
Selmoune, A., Cheng, Q., Wang, L., Liu, Z., 2020. Influencing factors in congestion pricing acceptability: a literature review. J. Adv. Transp. 2020. https://doi.org/10.1155/2020/4242964.
Siddique, M.A.B., Choudhury, C.F., 2017. Modelling the behavioural response to congestion pricing in Dhaka. Bangladesh. Transp. Dev. Econ. 3, 1–13. https://doi.org/10.1007/s40890-017-0052-y.
Singichetti, B., Conklin, J.L., Hassmiller Lich, K., Sabounchi, N.S., Naumann, R.B., 2021. Congestion pricing policies and safety implications: a scoping review. J. Urban Heal. 98, 754–771. https://doi.org/10.1007/s11524-021-00578-3.
Song, M., Li, Y., 2012. Feasibility study of urban road congestion pricing. Proc. - 2012 5th Int Conf. Intell. Comput. Technol. Autom. ICICTA 2012, 564–567. https://doi.org/10.1109/ICICTA.2012.148.
Souche-Le Corvec, S., Mercier, A., Ovtracht, N., Chevallier, A., 2019. Urban toll and electric vehicles: the winning ticket for Lyon Metropolitan Area (France). Res. Transp. Econ. 73, 17–33. https://doi.org/10.1016/j.retrec.2018.10.005.
Struyf, E., Sys, C., Voorde, E., Van De Vanelslander, T., 2022. Calculating the cost of congestion to society: a case study application to Flanders. Res. Transp. Bus Manag. 44.
Taherdoost, H., 2017. Determining sample size: How to calculate survey sample size. Int. J. Econ. Manag. Syst. 2, 237–239.
TfL, 2008. Impacts monitoring - Sixth Annual Report. Transp. London 3, Imagen PDF.
The Census of India, 2011. The Census of india 2011 report pdf. Goi.
TomTom, 2020. TomTom Traffic Index: Global Traffic Congestion Up as Bengaluru takes Crown of ' World ' s Most Traffic Congested City '. https://doi.org/29-12-2020.
Torrance, S., Froese, T., 2011. An inter-enactive approach to agency: participatory sense-making, dynamics, and sociality. Humana. Mente 15, 21–53.
USDOT, 2022. Benefits of Congestion Pricing [WWW Document]. FHWA. URL https://ops.fhwa.dot.gov/congestionpricing/cp_benefits.htm (accessed 8.4.23).
van Amelsfort, D., 2009. Behavioural Responses and Network Effects of Time-varying Road Pricing.
Vonk Noordegraaf, D., Annema, J.A., van Wee, B., 2014. Policy implementation lessons from six road pricing cases. Transp. Res. Part A Policy Pract. 59, 172–191. https://doi.org/10.1016/j.tra.2013.11.003.
Welch, T.F., Mishra, S., 2014. A framework for determining road pricing revenue use and its welfare effects. Res. Transp. Econ. 44, 61–70. https://doi.org/10.1016/j.retrec.2014.04.006.
Yamamoto, T., Fujii, S., Kitamura, R., Yoshida, H., 2000. Analysis of Time Allocation. In: Departure Time, and Route Choice Behavior under Congestion Pricing, pp. 95–101.
Zheng, Z., Ahn, S., Monsere, C.M., 2010. Impact of traffic oscillations on freeway crash occurrences. Accid. Anal. Prev. 42, 626–636. https://doi.org/10.1016/j.aap.2009.10.009.
Zhong, S., Xiao, X., Bushell, M., Sun, H., 2017. Optimal road congestion pricing for both traffic efficiency and safety under demand uncertainty. J. Transp. Eng. 143, 1–10. https://doi.org/10.1061/JTEPBS.0000025.