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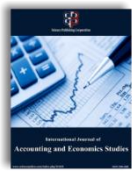

Pricing Perceptions and Digital Access in Public Transport: A Mixed-Methods Analysis of Satisfaction Drivers

Jane Weber

Bratislava University of Economics and Management, Furdekova 3240/16, 851 04 Bratislava, Slovakia
**Corresponding author E-mail: jane_weber@gmx.de*

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Abstract

Prices and affordability remain the most important factors for user satisfaction with public transport. However, the interplay between perceived price fairness and access to digital ticket channels has been little studied empirically to date. This study examines how different user groups evaluate price structures based on their ticket purchasing behaviour, socio-demographic background, and digital access, and how these dimensions jointly influence overall satisfaction. Based on the Customer Satisfaction Index (CSI), the Technology Acceptance Model (TAM), and Behavioral Pricing Theory, the study applies a sequential mixed-methods design that combines over 10,000 responses from a user survey with 14 expert interviews. Quantitative results show that digital access, combined with perceived fairness and price transparency, significantly increases satisfaction. However, pure digital discounts tend to marginalize older and digitally underserved users, thereby reinforcing perceptions of inequality. The results underscore price perception as a crucial aspect of service quality and call for inclusive, channel-neutral pricing strategies that adhere to the principles of fairness, accessibility, and digital justice in evolving mobility ecosystems.

Keywords: *Public Transport, Pricing, Customer Satisfaction, Digital Equity*

1. Introduction

In the context of sustainable urban mobility and the climate-driven imperative to shift from private to public transport, public transport pricing critically shapes user behavior, satisfaction, and loyalty. While affordability remains a well-established determinant in travel decision-making (Litman, 2022), increasing scholarly and policy attention is being directed toward users' perceptions of price fairness and accessibility in the digital era (Schweiger, 2023; Cziborra & Schulz, 2021). As ticketing systems increasingly adopt digital formats, ranging from mobile apps and online platforms to dynamic pricing tools, the question arises as to whether these innovations are equitably accessible to all user groups. Digital-exclusive pricing models, such as discounts available only via apps or online portals, may inadvertently disadvantage digitally marginalized populations, including older adults, individuals with limited internet access, or those lacking digital literacy (van Dijk, 2020; Buhling & Kulke, 2022). These dynamics can undermine perceived price fairness and reduce user satisfaction, potentially counteracting the intended benefits of digitalization in public transport systems. Recent technological developments, such as AI-based fare optimization and blockchain-enabled ticketing systems, have further accelerated the digital transformation of fare systems (Rail Pricing-RL, 2024; Global Mass Transit, 2024). While these innovations promise efficiency and personalization, they also raise new challenges regarding transparency, governance, and digital inclusion, particularly for mobility platforms aiming to integrate multimodal access in the form of Mobility-as-a-Service (MaaS) (Mdpi, 2024). This study addresses this emerging research gap by investigating how perceived price fairness and digital access jointly affect user satisfaction with public transport services. It also explores how these relationships vary across key sociodemographic variables such as age, gender, and travel behavior. Grounded in theories from behavioral economics, service quality and satisfaction research, and technology acceptance, this study aims to identify predictors of pricing satisfaction in digitalized fare systems. The results seek to inform evidence-based, inclusive pricing strategies that balance economic efficiency with social equity in the ongoing transformation of public transport.

2. Theoretical Framework

To examine the determinants of user satisfaction about public transport pricing and digital access, this study integrates three interrelated theoretical frameworks that capture economic, psychological, and technological dimensions of user perception and behaviour.
First, the CSI provides a proven model for conceptualizing satisfaction as a function of prior expectations, perceived performance, and confirmation or refutation of value (Fornell et al., 1996). In the field of public transport, the most important satisfaction factors include price transparency, value for money, and reliability of services, which together shape the perceived quality of service (Parasuraman et al.,

1988). Price perception is influenced not only by the actual amount of money but also by the perceived fairness of price structures, especially in the context of increasingly differentiated ticket channels.
Second, behavioral pricing theory suggests that consumers process price information through cognitive heuristics rather than rational calculations (Grewal et al., 1998; Homburg et al., 2005). Concepts such as reference prices, fairness norms, and framing effects significantly influence perceived value and satisfaction. In the area of public services, perceived price fairness is particularly important, as the same prices can be evaluated differently depending on the context, for example, depending on whether a ticket is purchased via an app or at a ticket machine (Zeithaml, 1988). Such perceptions can have a significant impact on behaviour, especially when digital channels are associated with exclusive benefits or discounts.
Third, the TAM assumes that the perceived usefulness and perceived ease of use of digital tools are the most important determinants of technology acceptance (Davis, 1989). Extensions of the model (Venkatesh et al., 2003) emphasise the influence of social norms, enabling conditions, and individual characteristics such as age, gender and digital literacy. In the context of public transport, the successful introduction of digital ticketing systems depends not only on technical functionality, but also on user trust, digital literacy, and the ability to access and use these systems (Czaja et al., 2006; Hunsaker & Hargittai, 2018).
To increase the theoretical relevance of this study, we also draw on recent literature dealing with equity and governance in digital fare innovations. For example, recent work on AI-driven pricing mechanisms shows how machine learning can personalize fare offers in real time but also raises concerns about the transparency and fairness of algorithms (Gao et al., 2023). Similarly, blockchain-based ticketing infrastructures are being explored for their potential to increase transaction security and reduce fraud while providing verifiable, user-owned mobility data (Zhang & Nambisan, 2023). In the area of governance, MaaS platforms face critical trade-offs between efficiency and inclusion, with research calling for stronger public oversight to ensure equitable access and accountability (Sadowski & Bendor, 2023). By synthesising these conceptual frameworks, this study proposes an integrated model in which digital access is positioned as a mediating factor between perceived price fairness and overall satisfaction. This conceptual integration is particularly relevant in hybrid tariff environments where analogue and digital channels coexist but may offer unequal benefits or usability, potentially leading to perceived exclusion of users with lower digital literacy.

3. Methodology

This study used a sequential mixed-methods design that integrated quantitative and qualitative approaches to investigate how digital access and perceived price fairness influence satisfaction with public transport. The complementary use of a representative large-scale survey and expert interviews ensured both breadth and contextual depth in the exploration of satisfaction factors.

3.1 Quantitative data and methods

The quantitative part is based on a longitudinal study on mobility conducted between 2019 and 2023 in a German metropolitan region. A total of 10,530 valid responses were collected using a mixed design combining computer-assisted telephone interviews (CATI) and an online panel. A stratified sample ensured proportional representation across important demographic variables such as age, gender, region type, and household size (Bethlehem & Biffignandi, 2012). The questionnaire included measures of satisfaction with public transport, perceived price fairness, primary ticket purchase channel, main mode of transport, frequency of use, age, gender, and household composition. Overall satisfaction was rated on a six-point Likert scale (1 = very dissatisfied, 6 = very satisfied) in line with national standards for mobility observation (infas, 2021). Descriptive statistics were used to examine the distributions of satisfaction scores and ticket behaviour. Group differences were tested using ANOVA with Bonferroni post hoc tests to identify significant effects between user segments. Finally, a multiple linear regression model was estimated to predict satisfaction based on perceived fairness, ticket channel, and demographic covariates. Interactions (fairness × channel; age × channel) were included to capture moderating dynamics. Standard error robustness and multicollinearity diagnostics (VIF) were performed to validate the model assumptions.

3.2 Qualitative data and analysis

The qualitative component consisted of 14 semi-structured expert interviews with representatives from transport authorities, digital mobility service providers, price consultants, and social inclusion organisations. Participants were selected through targeted sampling to ensure relevant expertise and sectoral diversity. The interviews were conducted using a theory-driven protocol developed from the conceptual approaches of behavioral pricing theory, the TAM, and digital equality frameworks. All interviews were audio-recorded, transcribed verbatim, and evaluated using a thematic analysis according to Braun and Clarke (2006). The data were manually coded using a hybrid approach that combined deductive codes with inductive themes emerging from the transcripts. The themes were developed through iterative coding cycles and validated through researcher triangulation. Three overarching themes emerged:

1. Perceived fairness and transparency, with scepticism towards purely digital discounts being prominent.
2. Access barriers and support needs, with a focus on older users and people with limited digital literacy.
3. Organisational challenges, with tensions between cost-efficiency goals and inclusion requirements being prominent.

To increase interpretative power, selected quotes were integrated into the analysis. For example, respondent no. 7 (public transport operator) explained: ‘We save money with the app, but that doesn't mean we should punish those who don't use it.’ Such quotes not only illustrate important findings but also strengthen the link between empirical findings and conceptual frameworks.

3.3 Conceptualization of digital access

In parallel with the empirical analysis, the study used a structured conceptualization of ‘digital access’ based on the literature on the digital divide. According to van Dijk's (2020) definition, digital access is a multidimensional construct that encompasses device ownership, connectivity, digital skills, and motivational factors. Accordingly, this study operationalizes digital access as a combination of:

1. Device ownership (smartphone or PC)
2. Stable internet connection (mobile or at home)
3. Digital competence and self-confidence (self-assessed familiarity with apps)
4. Availability of social support (e.g., help from relatives)

This broad operationalization reflects the recognition that exclusion from digital mobility services can be attributed to material, cognitive, and social limitations (Hunsaker & Hargittai, 2018). Taking these dimensions into account is essential when assessing the distributional effects of digital pricing strategies and their impact on satisfaction. To ensure terminological precision, the term 'digital access' is used consistently throughout the manuscript and replaces previously inconsistent terms such as 'access to digital tickets' or 'digital channels' unless a functional distinction is explicitly required.

4. Results

Descriptive analyses revealed that 41.7% of respondents primarily used digital ticket channels (mobile apps or online platforms), 33.5% used ticket machines, and 24.8% used traditional non-digital channels (e.g., staffed ticket counters, on-board purchases). The average perceived price fairness (measured on a 6-point scale from 1 = very fair to 6 = very unfair) was 2.3 for digital users and 3.1 for non-digital users. Accordingly, satisfaction was significantly higher among digital users (M = 2.32) than among non-digital users (M = 2.89). A multiple linear regression analysis was conducted to examine the predictors of overall satisfaction. The model explained 23.7% of the variance in satisfaction scores (adjusted $R^2 = 0.237$), which is considered robust in attitude research on transport behaviour (Friman et al., 2013; De Witte & Van Lierop, 2016). Perceived price fairness proved to be the strongest predictor ($\beta = 0.32$, $p < 0.001$), followed by the ticket purchase channel ($\beta = 0.15$, $p < 0.001$) and age ($\beta = -0.07$, $p < 0.01$). Gender was not a statistically significant predictor. All p-values are based on two-tailed significance tests. The VIFs were below 2.0, indicating no problematic multicollinearity. A significant interaction between perceived fairness and use of the ticket channel was found ($p < 0.05$). Non-digital users showed greater sensitivity to perceptions of fairness, especially in contexts where discounts were only available for digital channels. Among respondents aged 65 and older, both satisfaction and fairness scores were lowest when discounts were not offered in analogue formats. These quantitative results are compared with findings from the qualitative expert interviews. Three key themes emerged from the thematic analysis:

1. Perceived fairness and transparency: Experts expressed concerns about exclusive digital discounts. One participant noted: 'Many older users feel disadvantaged because they don't use smartphones. They don't understand why the same ticket costs more at the ticket machine.
2. Access barriers and need for support: Respondents emphasized that digital exclusion is not only based on the availability of technology, but also on a lack of digital literacy or support.
3. Organisational and financial trade-offs: Experts described internal tensions between cost-cutting measures and inclusion commitments. One expert emphasized: 'Our finance team appreciates the efficiency of app sales, but if that means losing a third of our passengers, we pay the price elsewhere'.

These issues underscore the need for transparent accounting in pricing. Inclusive prices may entail higher administrative and operating costs, for example, for maintaining a parallel ticketing infrastructure. However, these investments can reduce costs in the long term by avoiding user dissatisfaction, customer churn, or public criticism. A cost allocation approach that incorporates fairness considerations, such as the use of shadow prices or frameworks like social return on investment, can enhance budget planning and reporting in alignment with inclusive mobility objectives. Although the study is based on data from Germany, its findings are of general relevance, especially for countries undergoing digital transformation. In low- and middle-income countries where smartphone penetration is limited and internet access is restricted, there is a risk that exclusive digital pricing strategies will exacerbate transport inequalities. Policy makers in such contexts could benefit from implementing hybrid access strategies and universal design principles. This integration of quantitative and qualitative findings illustrates how perceptions of fairness, access restrictions, and financial impacts interact and influence user satisfaction. The results offer practical implications for pricing, operational planning, and the provision of inclusive services.

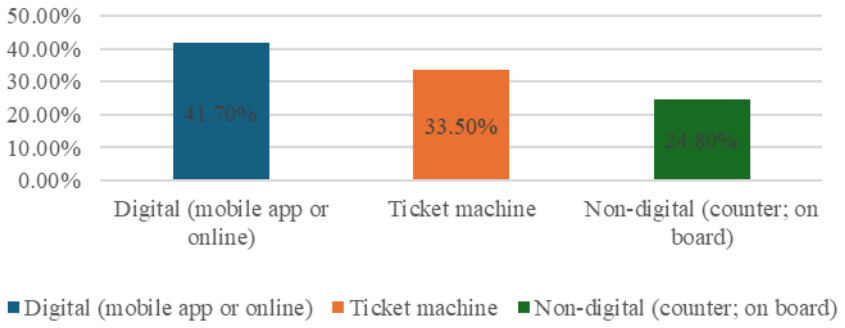

Fig. 1: own design Descriptive statistics of ticket channel usage, perceived fairness, and satisfaction

5. Discussion

The results of this study emphasise that satisfaction with public transport prices is influenced not only by objective costs, but also by subjective perceptions of fairness and accessibility. In line with behavioral pricing theory, users evaluate prices about internalized reference points, perceived entitlements, and purchasing conditions (Grewal et al., 1998; Homburg et al., 2005). The CSI model confirms that perceived value, especially for subsidized or indispensable public services, is central to user satisfaction (Fornell et al., 1996; Zeithaml, 1988). From an accounting perspective, these findings have important implications for cost allocation, budget planning, and financial transparency. If pricing strategies systematically exclude certain user groups from discounts or benefits, dissatisfaction can lead to reputational damage, higher complaints about the service, and ultimately to passenger losses, resulting in indirect costs that are not always considered in traditional budgeting models. Inclusive pricing may incur upfront costs (e.g., analogue infrastructure, onboarding campaigns), but these should be viewed as investments in long-term sustainability and equity that can be justified through cost-benefit analyses or social return on investment frameworks. This study also contributes to research in the field of digital equity by showing that users with limited digital access, defined by device availability, connectivity, digital skills, and support (van Dijk, 2020; Hunsaker & Hargittai, 2018), report significantly lower satisfaction and perceptions of fairness. These users benefit less from app-based discounts or real-time information services.

The TAM (Davis, 1989; Venkatesh et al., 2003) supports the view that perceived ease of use and usefulness are key factors in acceptance and that the user experience suffers when these are impaired by digital exclusion. The qualitative interviews complemented this interpretation: while many experts recognised the economic reasons for app-based pricing (e.g., lower distribution costs), several warned against excluding digitally disadvantaged population groups. The most common recommendations included:

- Introducing channel-neutral pricing, whereby all users have access to the same discounts regardless of how they purchase their tickets.
- Increasing price transparency, especially at ticket machines and counters.
- Providing inclusive guidance through digital training or hotlines.

These recommendations reflect not only ethical and political considerations but also practical measures to mitigate risks in budgeting, where overlooked equity issues can lead to downstream operational and reputational costs.

5.1 Geographical transferability and international relevance

Although this study is based on data from a digitally advanced German metropolitan area, the wider implications for other regions are highly relevant. Germany benefits from a well-developed digital infrastructure, multimodal transport services, and institutional mechanisms for social inclusion. However, the results also reveal weaknesses that may be even more pronounced in lower-income or less digitally developed regions. In regions with low smartphone penetration or unstable internet connections, such as parts of Eastern Europe, Latin America, or sub-Saharan Africa, exclusive digital prices can exacerbate socio-spatial inequalities in access to transport services (GSMA, 2023). Similar concerns have been raised in studies on MaaS platforms, where smart pricing models could inadvertently marginalize digitally excluded groups (Ziemke et al., 2024). Nevertheless, the principles identified here, channel parity, inclusive design, and digital onboarding, are transferable if adapted to local technological and socio-cultural contexts. For example:

- Bogotá has introduced TransMilenio, a hybrid ticketing system and community-led training for older users to break down barriers (Rodríguez & Targa, 2019).
- The Swedish Public Transport Act mandates price parity and funds analogue channels in underserved regions (Transport Analysis, 2022).
- India's Namma Metro is testing AI-powered kiosks with multilingual interfaces to bridge digital literacy gaps (Kumar et al., 2023).

We recommend further comparative studies that apply this framework, linking price fairness, digital access, and satisfaction, to different regions and platform types. Particular attention should be paid to governance structures in Mobility-as-a-Service systems, including how financial accountability, data transparency, and social justice are implemented in digital pricing algorithms.

In summary, satisfaction with public transport can be ensured not only by aligning pricing models with economic efficiency, but also with the principles of fairness, access, and accountability. This integrated approach contributes both to academic discussion and to actionable innovations in public services.

5.2 Policy and Practice Implications

From a policy and governance perspective, the findings of this study yield critical insights for the development of inclusive and equitable public transport pricing in digitally transforming environments. The overarching goal should be to align digital innovation with principles of fairness, transparency, and social inclusion.

First, it is essential to ensure procedural fairness through channel-neutral pricing. As emphasized in previous literature (Schweiger, 2023; Cziborra & Schulz, 2021), pricing parity across digital and analog access modes helps prevent the exclusion of digitally underserved users, particularly older adults and low-income populations lacking internet access or digital literacy. Ensuring equal pricing regardless of channel reduces perceptions of injustice and reinforces trust in public institutions.

Second, transparency standards should be uniformly applied to all ticketing channels. Users must be able to understand the underlying pricing logic, whether purchasing via app, vending machine, or staffed counter. Interface design should communicate discounts, eligibility criteria, and dynamic fare adjustments clearly and accessibly.

Third, user experience research and continuous stakeholder engagement are imperative to incorporate the needs and constraints of digitally underserved groups. Participatory approaches, such as co-design workshops and focus groups, can yield actionable insights for interface improvements and communication strategies.

Fourth, public communication campaigns must actively inform users about pricing schemes, available support, and eligibility for reduced fares. Inclusive outreach strategies are especially important in socioeconomically diverse regions, where information asymmetries may compound digital exclusion.

Fifth, service monitoring and evaluation frameworks should explicitly include indicators related to perceived fairness, accessibility of digital services, and user satisfaction across demographic segments. These data-driven feedback loops can help identify unintended exclusionary effects of digital pricing models early and support course corrections.

5.3 Accounting Implications for Inclusive Pricing Strategies

In addition to these policy-level considerations, the adoption of inclusive pricing strategies carries substantial implications for public sector accounting, cost management, and financial governance. First, channel-neutral pricing alters the internal cost structure of transport operators. While digital sales platforms (e.g., apps, online portals) tend to reduce marginal transaction costs due to automation and self-service capabilities, analog channels (e.g., staffed counters, ticket machines) incur higher fixed and variable costs related to labor, maintenance, physical infrastructure, and fraud mitigation (Gómez-Lobo, 2021). Ensuring pricing parity across these channels requires explicit cost attribution and cross-subsidization strategies, which must be accounted for transparently in annual financial statements and internal cost centers.

Second, budget planning and forecasting become more complex in inclusive pricing systems. Operators must anticipate behavioral shifts (e.g., user migration from analog to digital channels), short-term revenue impacts of harmonized discount structures, and ongoing administrative expenses associated with inclusive outreach and onboarding campaigns. These factors should be incorporated into multi-channel cost-benefit analyses, as recommended by the OECD (2022) and contemporary public financial management frameworks.

Third, there is an increasing expectation from regulators, funding bodies, and the public for financial transparency in pricing decisions. This entails the publication of fare structures, cost justifications for subsidies, and outcome-based evaluations of digital transition strategies. Transparent and comprehensive reporting not only enhances internal accountability but also fosters public trust, an essential asset in publicly subsidized service sectors (Bovens, 2007).

To strengthen the accounting perspective, we recommend the integration of equity-relevant cost categories into transport operators' financial reporting systems. This includes tracking the share of budget allocated to inclusion efforts, cost-efficiency of analog support services, and the impact of pricing adjustments on ridership among vulnerable populations.

A promising example is the use of integrated financial and social reporting in Vienna's municipal transport operator Wiener Linien, where annual sustainability reports include KPIs on affordability, digital participation, and subsidization transparency (Wiener Linien, 2023). Similarly, Bogotá's Trans Milenio program has developed cost-monitoring dashboards that quantify equity-related operational expenses (Rodríguez & Targa, 2019). Future research should investigate the applicability of activity-based costing or performance budgeting models tailored to public mobility services. Such frameworks allow for more granular assessment of how resources are allocated in pursuit of both efficiency and equity goals, thereby bridging the gap between fiscal responsibility and social inclusion in transport policy. In low- and middle-income countries, cost transparency and analog fallback strategies become critical not only for social equity, but also for financial viability. Pilot projects in Nairobi (Ma3Route platform) and Bangalore (BMTC Smart Card initiative) demonstrate how mobile-first pricing must be adapted through offline-compatible payment systems and community-based onboarding to prevent digital exclusion (GSMA, 2023; Jain et al., 2023). These cases suggest that inclusive pricing should be embedded in broader mobility governance frameworks, linking fare policy, IT infrastructure, and accountability systems.

6. Conclusion

This study demonstrates that user satisfaction with public transport is not solely a function of objective affordability but is strongly shaped by perceived pricing fairness and the accessibility of digital ticketing channels. As public transport systems increasingly integrate digital platforms, ranging from mobile apps to dynamic pricing algorithms, the risk of digital exclusion becomes a central concern in maintaining user trust and long-term ridership. The quantitative results confirm that users with access to digital channels not only report higher satisfaction but also perceive pricing as fairer, an effect that is particularly pronounced among younger and digitally literate users. In contrast, analog users, especially older adults or those without internet access, tend to perceive pricing structures as less transparent and less equitable. These disparities are not just technological but also reflect underlying social inequalities, aligning with prior research on the digital divide (van Dijk, 2020; Hunsaker & Hargittai, 2018). The qualitative findings further illuminate the organizational and normative tensions in implementing equitable pricing strategies. While digital channels offer efficiency gains and operational cost savings, they must not come at the expense of procedural fairness. Experts emphasized the importance of channel-neutral pricing, inclusive onboarding measures, and governance mechanisms that proactively address the needs of digitally marginalized groups. From a policy and accounting perspective, the findings call for an integrated approach to digital transformation in public transport. Fare systems must balance cost-efficiency with social inclusion objectives, supported by transparent reporting practices, budgetary planning for analog support structures, and the development of financial indicators that reflect equity-oriented outcomes. In summary, user-centred digitalization in public transport must be grounded in three guiding principles:

1. Inclusion – All users, regardless of digital literacy or access, must be able to participate in and benefit from fare innovations.
2. Transparency – Pricing logic and discount structures must be communicated across all channels.
3. Channel fairness – Equal treatment across digital and analog access points is essential to preserve trust and social cohesion in mobility systems.

To achieve these goals, public transport operators and policymakers must embed fairness and accessibility into both their technical design choices and their financial planning frameworks. Only then can digitalization serve not as a new barrier, but as a tool for equitable, resilient, and user-friendly public transport in the 21st century.

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