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Comparison of Total Trip Costs for Shared Micromobility and Public Transport: A Case Study in Košice

Porovnanie celkových nákladov na cestu pri zdieľanej mikromobilite a verejnej doprave: prípadová štúdia v Košice

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Abstract: As urban areas face increasing congestion and environmental issues, shared micromobility has become a key solution for sustainable transport and 'first- and last-mile' connections. This research assesses the competition between shared e-scooters and Public Transport in Košice through Monte Carlo simulations and Generalized Travel Cost (GTC) analysis using actual trip data. By running 10,000 scenarios with different parameters, the study captures variations in costs, time value, and comfort factors, including transfer disutility. Results show e-scooters are very effective for short trips (under 15 minutes) because they save time and reduce GTC. A loyalty-based half-price discount significantly increases their advantage; in cases requiring transfers to Public Transport, e-scooters are favored up to 97.6% of the time. For longer trips, e-scooters serve a complementary first- and last-mile role. The findings highlight that targeted, loyalty-driven pricing strategies strongly influence urban mode choice and can boost market share for short-distance travel.

Key words: *Shared Micromobility. Generalized Cost. Public Transport. Mode Choice Modeling.*

JEL Classification: R41. L92.

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Introduction

Micromobility typically includes personal transport options with vehicles weighing up to 350 kg and reaching speeds of up to 45 km/h. These vehicles operate either through human power or electric assistance. The category covers a wide range of modes, such as bicycles, e-bikes, scooters, e-scooters, mopeds, skateboards, and similar small transportation devices. Designed mainly for short trips, micromobility has become very popular, especially in urban settings. Its key advantage is efficiency: it takes up minimal space and simplifies point-to-point travel, helping reduce congestion and better use public areas (ITF, 2020).

The significance of micromobility is evident across multiple domains, from sustainability to urban transport infrastructure planning. It plays a vital role in achieving the Sustainable Development Goals by helping reduce traffic congestion, greenhouse gas emissions, and the overall environmental burden in cities. Furthermore, it enhances traffic flow and complements public transport, thereby addressing the crucial "first and last mile" challenge. Beyond environmental and operational benefits, micromobility also has a positive impact on the economy: it creates new job opportunities, improves access to employment, and supports tourism growth. Finally, it positively influences public health by not only reducing harmful emissions but also actively encouraging physical activity and promoting active travel (Olabi et al., 2023).

There is currently no consensus in the scholarly literature on the primary psychological drivers of micromobility adoption or the specific obstacles that limit the broader use of these shared systems. This paper aims to contribute to this ongoing debate by examining users' potential economic incentives in depth. We analyze from the perspective of total trip utility, factoring in travel time costs and perceived comfort. This study uses a simulation model based on real-world micromobility data from Košice.

This study aims to quantify and compare the Generalized Travel Costs (GTC) of shared e-scooters and public transport on short urban routes, using Košice as a case example, considering existing research gaps. It first identifies the points at which the two modes become competitive or complementary by considering factors like time variability and perceived comfort, including transfer disutility. The research further examines how mode choice responds to strategic pricing incentives, with particular focus on operator loyalty discounts that can significantly alter the GTC advantage. Additionally, the study places these findings within the wider context of the "private vs. public" service provision debate and externality management issues such as spatial disorder and environmental impact. These objectives collectively support understanding user economic drivers and the development of strategic recommendations for private operators and public transport agencies to promote sustainable urban mobility.

1 Literature Review

Shared micromobility has evolved through several distinct stages. Its earliest origins date back to the 1960s in the Netherlands, where the first free bicycle schemes appeared but faced challenges like vandalism and theft. In the 1990s, Denmark introduced systems with docking stations and coin deposit machines. A breakthrough happened with the development of the "third generation" systems in France around 2007, which incorporated GPS and information technologies to improve security and tracking. Technological progress then led to the rise of dockless shared e-bike and e-scooter systems, which gained popularity around 2018, driven by companies like Lime and Bird. These modern systems enable users to travel directly to their destinations and park almost anywhere, a versatility that has driven their rapid global growth (Ghaffar et al., 2023).

Cities and transport providers currently focus on creating regulations to promote safety and accessibility. These regulations include setting speed limits, defining fleet sizes, and designating parking zones. Simultaneously, micromobility options are rapidly expanding for both private and shared use. In the shared transport model, users pay only to rent a vehicle rather than own one. This system encourages people to reconsider and likely reduce their reliance on private vehicle ownership (Singh & Bhattacharyya, 2023).

The ongoing urbanization trend has inevitably worsened traffic congestion, leading to more traffic jams, parking shortages, and overstretched public transit. Micromobility vehicles present an ideal solution to this problem because they can quickly cover short distances and have a small spatial footprint. This potential is fully unlocked when infrastructure such as dedicated cycle paths or reserved lanes is developed for these vehicles. Furthermore, micromobility is an environmentally friendly transport option that encourages technological innovation and attracts investments in electric vehicles with longer-lasting batteries and enhanced features (Singh & Bhattacharyya, 2023).

The COVID-19 pandemic notably influenced the adoption of micromobility. Restrictions on sharing enclosed public transport spaces prompted people to seek safer physical distancing options. This situation increased interest in using micromobility vehicles for short trips to reduce infection risk. Importantly, this change in behavior and the boost in micromobility use have continued even after the pandemic ended (Li et al., 2021).

A notable aspect of micromobility is its relatively narrow socio-economic and demographic user profile. Males consistently make up the majority of electric scooter users (Christoforou et al., 2021; Laa & Leth, 2020; Hosseinzadeh et al., 2021; Jiao & Bai, 2020; Nikiforiadis et al., 2021). Studies on the influence of educational attainment have yielded mixed results, though several indicate higher adoption among those with higher levels of education (Laa & Leth, 2020; Bai et al., 2021; Clewlow & Mishra, 2017). This demographic tends to overlap significantly with typical micromobility users (McKenzie, 2019; Mouratidis, 2022; Reck et al., 2022), who often replace walking, cycling, or public transport with micromobility options (Le Boennec & Salladarré, 2023; Christoforou et al., 2021; Oeschger et al., 2023; Bai et al., 2021). Their use of micromobility as a substitute for private car trips remains limited (Asensio et al., 2022; Felipe-Falgas et al., 2022; Roig-Costa et al., 2024; Teixeira et al., 2021; Liao & Correia, 2021; Wang et al., 2022).

Factors such as accessibility and flexibility are often highlighted as key benefits of micromobility (Guo & Zhang, 2021; Eccarius & Lu, 2018; Popovich et al., 2014), along with travel time savings (Bateman et al., 2021; Glavic et al., 2021; Kaplan et al., 2018), and ease of use and comfort (Rejali et al., 2021; Hardt & Bogenberger, 2019; Teixeira et al., 2021). While these aspects create a competitive edge over traditional transportation, many people are discouraged by notable drawbacks. The most significant is safety concerns (Teixeira et al., 2023; Bretones et al., 2023; Fitt & Curl, 2020; Mitra & Hess, 2021). For shared micromobility, additional issues include difficulty finding a nearby vehicle or encountering a damaged or dead-battery vehicle. In private ownership, concerns about theft or limited travel range are primary deterrents (Krauss et al., 2022; Patil & Majumdar, 2021). The role of economic factors remains unclear, as costs can either motivate or hinder adoption depending on the broader context (Abouelela et al., 2021; Eccarius & Lu, 2020; Hyvönen et al., 2016; Rejali et al., 2021).

1.1 Shared Mobility

Shared mobility is a modern transportation approach allowing multiple people to share vehicles for their trips. It includes various types of vehicles, both traditional and electric. Short-term rentals are suitable for short urban distances. Unlike traditional transportation, which typically involves personal ownership and single-user use, shared transport provides publicly accessible vehicles that users rent for a limited time.

This segment's growth is driven by technological advances, rising demand for flexible, affordable transportation options, and an increasing focus on environmentally sustainable solutions. The shared mobility industry is growing steadily, with global revenues expected to reach USD 1.56 trillion by 2025 and increase to USD 1.78 trillion by 2029, at a CAGR of 3.43%. Considering ongoing trends toward sustainability, digitalization, and transport efficiency, it is reasonable to expect this sector will continue to expand and evolve (Statista, 2025).

Although this mode of transport has been around since the mid-20th century, it is now gaining popularity. This renewed interest is mainly due to technological advances like GPS and the widespread use of smartphones.

Shared transport is commonly seen as an efficient, flexible, eco-friendly, and less expensive option compared to taxis. Users just pay for the ride, saving on the costs of buying a vehicle, avoiding maintenance expenses, and usually having a vehicle available across the city (Sprei, 2018).

Shared mobility mainly serves larger urban areas where high population density supports efficient vehicle operation. In contrast, its use is uncommon in smaller towns and rural regions. A significant reason for this limited uptake is that rural residents often travel longer distances daily for work or school. Consequently, renting shared micromobility options becomes less practical, as it may involve higher costs and more time than other alternatives (Wendering, 2025).

Various shared transport vehicles exist, differing in accessibility, use, and target users. The most common and widely used micromobility options are bicycles, e-bicycles, e-scooters, and e-mopeds. Nonetheless, the particular combination of vehicles available varies depending on each shared transport provider and their operational area.

Shared micromobility operates mainly through two frameworks: free-floating and station-based. The station-based system requires users to pick up and return vehicles only at designated docking stations, which are strategically placed around the city near major landmarks and shopping centers. This setup keeps vehicles confined to these stations, preventing obstruction of pedestrian pathways. In contrast, the free-floating system allows users to pick up and drop off vehicles at any location within a designated operational area. Its key benefit is increased convenience, as users can end their rides exactly where they want (Doglione, 2024).

The literature highlights several key differences between private micromobility and shared systems. Shared mobility options are often used for shorter trips (Laa & Leth, 2020; Reck et al., 2022) or as components of multi-modal journeys (Oostendorp & Hardinghaus, 2023; Gössling, 2020). In contrast, private micromobility tends to replace private car use, even over longer distances.

In real-world settings, shared micromobility is a system deployed in numerous European cities. Some municipalities have successfully integrated these services, but others have encountered substantial implementation difficulties, resulting in strict operational limitations or the outright removal of the services.

Paris was among the first European cities to introduce shared e-scooters in 2018 as a new urban transportation option. Soon after, e-scooters gained rapid popularity, leading many providers to enter the market. While thousands of scooters circulate through Paris every day, residents have raised growing safety concerns, largely because some users do not operate them responsibly. As a result, in 2020, the city implemented some of the strictest regulations for shared e-scooters, including notable speed limits. This initial regulatory measure proved inadequate, leading to a 2023 referendum where 90% of voters supported a total ban on shared e-scooters. After this ban, shared bicycle use increased sharply citywide, including among tourists (Carey, 2024).

Shared micromobility in Copenhagen has experienced notable changes recently, initially resembling Paris's situation. In 2019, the city saw a huge increase in shared e-scooter demand, with the number of operators soaring to around 20. The lack of regulation caused problems: scooters cluttering streets and sidewalks, often being dumped in harbours and canals, leading to public outrage. This led to a temporary ban lasting until 2021. Before reintroducing the service, Copenhagen adopted stricter rules, capping e-scooters at 3,200, limiting operations to four licensed companies, and requiring parking outside the city centre. Today, e-scooters help decrease car use and support public transit (Hansen, 2023).

Lisbon, Portugal, is renowned for its hilly landscape, which can make shared micromobility deployment, especially e-scooters, challenging. Nonetheless, Lisbon has maintained a shared micromobility system since 2018. Currently, five operators offer these services, all of whom entered into a regulatory agreement with the city in 2023 concerning shared scooters and bicycles. This agreement set explicit limits on the maximum number of vehicles allowed in the city, capped the speed of shared vehicles at 20 km/h, and required the development of a map indicating designated parking areas (LPP 2023).

Across many European cities, similar patterns are visible in how micromobility adoption and regulatory restrictions develop. However, the question remains: what about people who don't currently use this mode of transport? Only a few studies have explored this issue. For example, Eccarius & Lu (2020) noted that leveraging respondents' existing positive views on micromobility's environmental benefits could boost their intention to use it, based on a Taiwan case study. Bao & Yi (2022) found similar results, showing that behavioral interventions targeting areas respondents consider important are effective in environmental, economic, and efficiency aspects. Moreover, they showed that internal focus in behavioral strategies is more successful than external approaches.

In Slovakia, research on this topic is still in its early stages. However, micromobility remains highly relevant to our local context, as reflected in official documents like the 2022 Update of the City of Košice's Transport Strategy. This document highlights micromobility, including e-scooters, as a key solution to reduce urban traffic problems. Most studies (Kalašová & Čulík, 2023; Pribula et al., 2024; Braniš et al., 2020; Kubaľák et al., 2021; Štefancová et al., 2022) have mainly examined the current usage of micromobility or its potential deployment. Nevertheless, they have paid less attention to specific strategies to increase adoption or to the existing barriers that hinder its use.

Therefore, the subsequent sections of this study aim to explore the role of economic factors as potential motivators for the use of shared micromobility systems, specifically by comparing them with public transportation, using the city of Košice as a case study.

1.2 Challenges of Shared Mobility

Although shared micromobility is seen as an important tool for reducing greenhouse gas emissions and supporting sustainable development, its overall environmental benefits are challenged by energy storage issues. Notably, the extraction of raw materials such as lithium and cobalt—crucial for electric vehicle batteries—raises significant environmental and ethical concerns (Sun et al., 2020). Additionally, the increasing accumulation of waste batteries presents a major obstacle. Inefficient recycling methods and improper disposal of hazardous waste at the end of vehicle life can cause further damage to ecosystems (Harper et al., 2019).

Shared micromobility's growth in cities is closely connected to the gig economy, which depends on independent workers completing short-term tasks through digital platforms. A major issue threatening its social sustainability is the high work precarity caused by unclear legal statuses, as many workers are classified as independent contractors. These workers often operate in a legal 'gray area,' economically reliant on the platform but lacking employee rights, resulting in the absence of social protections and traditional benefits (Koutsimpogiorgos et al., 2020). Worker insecurity is worsened by algorithmic management, with platforms transferring risks and costs, such as unpaid work for searching or waiting for tasks, straight to the workers. Therefore, there is an urgent need for laws and oversight in this sector to safeguard workers' rights and uphold 'decent work' principles amid ongoing urban changes (Kozar & Bolimowski, 2024).

A major institutional concern with shared micromobility is how initially cooperative systems can gradually evolve into predatory oligopolies or monopolies that control urban transportation (Brabet et al., 2020). This evolution is fueled by 'economies of density,' where platform scale benefits users and naturally leads to market concentration and increased power for dominant firms (Rosaia, 2020). These major platforms leverage accumulated user data and network effects to create barriers to entry for competitors, raising the risk of 'market enclosure,' in which a few players control access to mobility and digital city infrastructure (Brabet et al., 2020). Although market concentration can bring operational benefits, such as fewer idle vehicles, simulation studies indicate that monopoly advantages often come at the expense of passenger welfare through higher prices (Rosaia, 2020). Additionally, in a multi-oligopoly setting, aggressive pricing, rapid technological changes, and market chaos can occur, harming startups and strengthening the position of large, established tech companies (Zhang et al., 2024).

The shared micromobility industry is still in its early phase, marked by high market volatility and uncertainty about future business models (Aarhaug et al., 2023; Mandouri et al., 2025). During this startup stage, it’s common to see price dumping, with operators setting tariffs below costs to gain market share. These prices generally move upward as the market develops (Aarhaug et al., 2023). The sector is heavily shaped by rapid advances in technology, especially in lithium-ion batteries and energy storage, which impact vehicle lifespan and operational costs (Carvalho et al., 2025; Janczewski & Janczewska, 2025). While 2030 projections show a significant rise in global market value, the sector's long-term stability will hinge on tighter regulations, infrastructure growth, and increased vehicle use (Janczewski & Janczewska, 2025; Mandouri et al., 2025). Consequently, current pricing trends are temporary and expected to change fundamentally as the urban transport ecosystem matures over the next decade (Aarhaug et al., 2023; Janczewski & Janczewska, 2025).

The growth of shared micromobility is closely tied to the issue of urban clutter caused by unregulated parking of devices in cities (Aarhaug et al., 2023; Janczewski & Janczewska, 2025). This problem mainly stems from the dockless service model, which allows users to leave vehicles at their final stops without considering public space management. As a result, sidewalks often become blocked, and pedestrian movement is disrupted, creating negative effects for non-users and local residents (Mandouri et al., 2025). Case studies from cities like Copenhagen highlight the seriousness of this problem, with abandoned e-scooters clogging walkways and sometimes ending up in harbours and canals. Therefore, current research calls for tighter regulations, such as designated parking zones and mobility hubs. Experts also believe that managing and allocating urban space for these vehicles should be the responsibility of municipalities, not left to private platform operators (Janczewski & Janczewska, 2025).

2 Material and Methodology

Our analysis of the economic feasibility of shared micromobility is based on trip data from Antik, one of the operators of shared micromobility systems in Košice. Figure 1 shows the company's operational area in Košice.

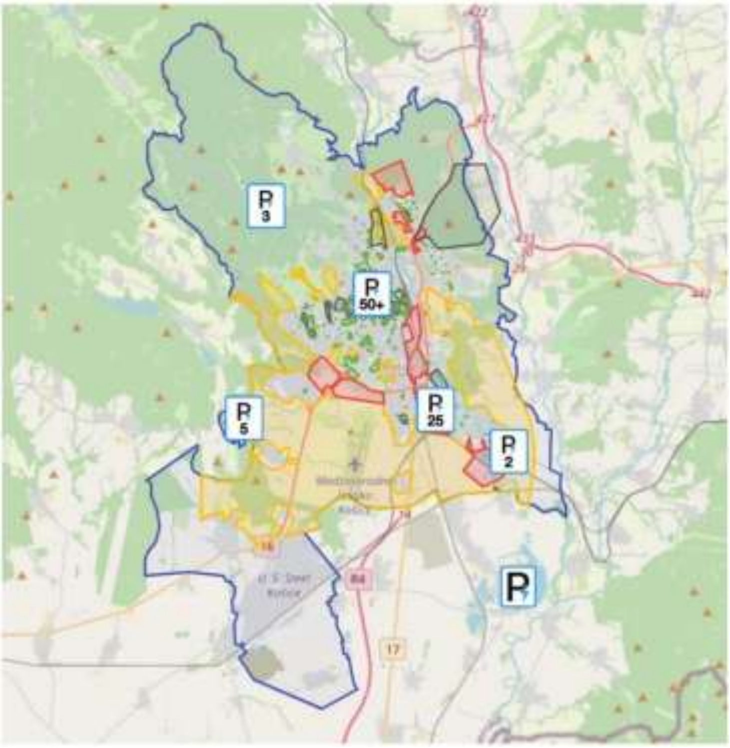

Figure 1 Operational Zones of Shared Transport Vehicles Provided by Antik
Source: ANTIK SmartWay

These data include records of e-scooter trips from 2021 to 2023. This trip information will later serve as input for a simulation to compare the travel costs of the shared micromobility system with those of public transport. Antik's data included the following details: the time of use of the shared vehicle, rounded to the nearest hour; the latitude and longitude of the trip's origin and destination; and the addresses of the start and end points.

The data we obtained did not include details on routes or travel times for individual trips. To fill this gap in later analysis, we used the Google Maps Platform Directions API to find the routes between each trip's origin and destination. This tool helps identify the most efficient route by accounting for factors such as travel time and distance.

For each pair of origin and destination coordinates, we sent a request to the API, which provided an encoded route. We decoded this route with the googleway library in R, reconstructing each trip's path as a sequence of points. The leaflet library in R was then used to visualize the results, allowing interactive display of routes and travel times on a map. The processed data are shown in Figure 2.

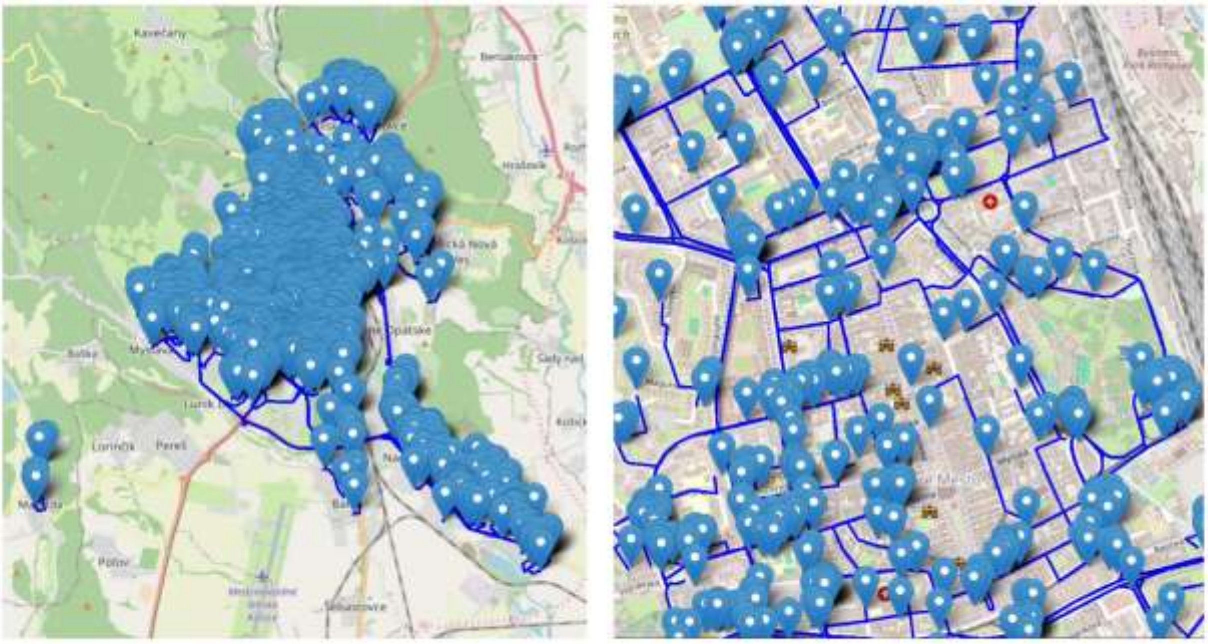

Figure 2 Trip Origins, Destinations, and Reconstructed Routes within the City of Košice
Source: Own processing

2.1 Simulating the Economic Viability of Shared Micromobility

To compare the use of shared micromobility and public transport, a Monte Carlo simulation was chosen to account for the variability in individual factors (Harrison, 2010). In the cost-benefit analysis between e-scooters and public transit, we identify the Generalized Travel Costs (GTCs) for each mode. For an e-scooter trip, key costs include the rental fee and time costs, such as walking to find an available scooter and the actual travel time. In contrast, public transport costs encompass fares, in-vehicle time, walking to the stop, and waiting time for the vehicle.

This study's Monte Carlo simulation centers on its stochastic method for managing the natural variability and uncertainty in individual travel factors. Unlike deterministic models that rely on fixed estimates, this approach employs repeated random sampling to produce a spectrum of possible results; specifically, 10,000 iterations were performed for each of the 10 scenarios. During each cycle, the model randomly draws values for critical parameters, such as time value, walking time weights, and transfer penalties, from predefined probability distributions based on empirical data. By combining these numerous simulations, the study constructs a comprehensive distribution of total trip costs instead of a single static figure, effectively reflecting the variety of user perceptions and travel conditions in Košice.

In addition to the financial and time costs, comfort is an important factor. Public transport can cause discomfort due to transfers between lines or overcrowded vehicles, both of which degrade the journey experience (European Commission, 2014).

Therefore, the Generalised Travel Costs for micromobility (specifically e-scooters, denoted by *i*) and for public transport (denoted by *j*) are calculated as follows:

$$GTC_i = \text{price} + \text{TV}\ (T_{IVT(i)} + \beta_{walk} T_{walk(i)}) \tag{1}$$

$$GTC_j = \text{price} + TV\ (\beta_{IVT} T_{IVT(j)} + \beta_{walk} T_{walk(j)} + \beta_{wait} T_{wait(j)} + \beta_{transfer} N_{transfer(j)}) \tag{2}$$

where:

GTC_i is Generalised Travel Costs for e-scooter

GTC_j is the Generalised Travel Costs for public transportation

$price$ is the monetary cost (price) paid for the e-scooter ride / public transport journey

TV is the value of time

T_{IVT} is the In-Vehicle Travel Time

T_{walk} is the walking time to the vehicle

T_{wait} is the time spent waiting for the public transport vehicle

$N_{transfer}$ is the number of transfers required during the journey (as a proxy for discomfort)

β_{IVT} is a coefficient representing the perceived unit cost of in-vehicle time

β_{walk} is the coefficient representing the perceived unit cost of walking time

β_{wait} is a coefficient representing the perceived unit cost of waiting time

$\beta_{prestup}$ representing the monetary penalty (discomfort cost) associated with each transfer

As no experimental research has been carried out in Košice to determine the specific coefficients for local conditions, we used the average values from a similar study on the Bordeaux case (Kalakoni et al., 2024) in our simulation.

$$\beta_{IVT} = \begin{cases} 1, \text{for e} - \text{scooter and public transportation trip during normal condition} \\ > 1, \text{for public transportat trip during peak hours} \end{cases}$$

$\beta_{walk} = 1{,}63$, based on European-wide evidence

$\beta_{wait} = 1{,}60$, based on European-wide evidence

$\beta_{transfer} = 5\ min$, penalty for transfers within the same transport mode

$T_{walk} = 2\ min$, the average value used for e-scooter trips, based on evidence from a survey of shared e-scooter service users in Paris.

Based on these values, intervals were subsequently established, from which the respective coefficients were generated for the simulations as:

- β_{IVT} = (1.0; 2.0)
- β_{walk} = (0.5; 2.5)
- β_{wait} = (0.5; 2.5)
- $\beta_{transfer}$ = (3.0; 7.0)

The Value of Time (TV) was determined based on a 2021 survey conducted by the Institute of Transport Policy, which established that the value of one hour spent by a traveller in a vehicle during a private journey is €4.86 (Ministerstvo dopravy a výstavby Slovenskej republiky, 2022).

A student commuting to the Technical University of Košice (TUKE) was chosen as a representative model for the upcoming simulation settings. This student travels from nearby villages or towns, mainly using train or bus services (SAD). After arriving at the main station, the student needs to continue to TUKE or vice versa. For this key part of the journey, they can choose from public transport (buses or trams), shared mobility services, private taxis, or walking. In this case study, we extracted relevant e-scooter routes from real-world data provided by Antik, using the R programming environment. We specifically selected routes where the origin is within 500 meters of the train or bus station and the destination is within 500 meters of TUKE, or vice versa. Figure 3 shows an example of these trips, with blue dots marking origins and red dots indicating destinations. This visualization forms the basis for further analysis, comparing the costs and travel times of different transport modes between the station and the university.

The dense cluster of blue points (trip origins) near TUKE indicates that most e-scooter trips start there. This likely reflects students using e-scooters to commute from the university to the main station on their way home. On the other hand, the concentration of red points (trip destinations) around Staničné námestie (Station Square) suggests that this area mainly functions as a destination for students.

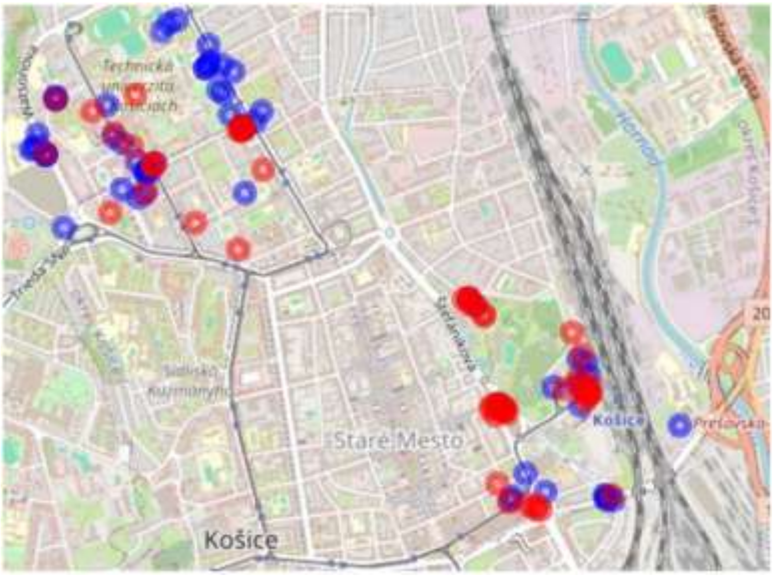

Figure 3 Sample of Trip Origins and Destinations Selected for the Simulation
Source: Own processing

Table 1 Public Transport Fares and Subscriptions in Košice

FARE TYPE	STANDARD	REDUCED
30 MIN	€1.00	€0.50
60 MIN	€1.20	€0.60
24 HOUR.	€3.80	€1.90
7 DAYS	€12.00	€6.00
NIGHT FARE	€1.50	-
30 DAYS	€25.00	€12.50
90 DAYS	€68.00	€34.00
180 DAYS	€126.00	-
365 DAYS	€199.00	€99.50

Source: https://www.dpmk.sk/prepravne-podmienky/tarifa-tarifi

This analysis aims to determine whether public transport (PT) or shared mobility (Antik shared scooters) provides a greater economic benefit to the individual user. The model's price variable will represent the fare for public transit or the rental cost of a shared scooter. The public transport ticket fare data presented in Table 1 are sourced from the official website of the City of Košice's Transport Company (valid at the time of model implementation).

Public transport fares are quite affordable. An hourly ticket is €1.20, while a half-hour ticket costs €1.00; both are valid for transfers. A monthly pass, priced at €25.00, grants unlimited travel on municipal transport during its validity. The Transport Company provides discounted tickets and subscriptions for children, students, seniors, and Severe Disability Pass/Card holders, with prices halved compared to standard fares.

Regarding shared mobility, Table 2 displays the tariffs (fares) for travel using Antik's shared e-scooter system.

Table 2 Antik Service Pricing – Shared E-scooter

SERVICE DESCRIPTION	**Price**
Per started minute of rental (new customer)	€0.20
Per started minute of rental (loyal customer)	€0.10
Fee for ending the rental in the Free Return Zone	€0.00
Fee for ending the rental in the Paid Return Zone	€1.00
Fee for ending the rental outside a charging station with a battery charge below 5%	€30.00
Fee for ending the rental outside the usage zone, including No-Ride Zones and No-Return Zones	€70.00

Source: https://www.antiksmartway.sk/sk

Shared mobility typically costs more than public transport. Users pay €0.20 per minute, so a 30-minute trip amounts to €6.00. In contrast, public transport costs about €1.00 for the same duration. This makes public transport more affordable after just 5 minutes of travel, especially for those with a subscription.

The rental cost of shared e-scooters clearly varies based on the customer's status, whether new or loyal. Additionally, the chosen drop-off point can significantly affect the total price, as incorrect returns may incur substantial extra fees. A Loyal Customer is officially defined as someone with an active Antik contract for services such as internet, TV, or phone, with no outstanding payments. In contrast, a New Customer is someone without a current contract for any of Antik's services, including those who specifically sign up for the shared mobility service.

Since our model agent is a student, we use the discounted public transport fare; shared mobility services like Antik do not offer such discounts. Currently, a discounted 30-minute public transport ticket costs €0.50, a student monthly pass is €12.50, and a three-month pass is €34.00. In contrast, Antik shared scooters cost €0.20 per minute for new users and €0.10 per minute for loyal customers. Trip durations were estimated using recommended routes from Google Maps. For public transportation, the only direct route from the station to the Technical University is Bus Line 19, which runs every 20 minutes and takes 8 minutes in-vehicle.

Alternatively, a two-tram trip (Lines 2 and 7) requires a transfer, with trams running every 15 minutes, a total IVT of 12 minutes, and a transfer wait time of 4 minutes.

For e-scooters, we calculated travel time using Antik data. The distance between the station and the Technical University is 2.3 km, and the average e-scooter speed in an urban environment is 10-15 km/h. The travel time in our case was thus estimated at 12 minutes. This estimate subsequently serves as input for calculating both the price of the shared scooter ride and the Value of Time component. The walking time to the vehicle, T_{walk} for shared mobility, was determined as the time required to walk from the station to the Antik charging hub, given that the Antik hub is located almost immediately outside the train station entrance and a 3-minute walk from the bus station, the average walking time to the vehicle is 2 minutes. Similarly, public transport stops are situated directly at the station, and the average walking time from both stations is 2 minutes according to Google Maps. Therefore, the parameter T_{walk} was set to 2 minutes for both transport options.

Table 3 Parameters of Individual Scenarios

Scenario	**Antik Customer Status**	**Scooter Price (€/min)**	**Public Transport Ticket Type**	**Public Transport Ticket Cost (€/trip)**	**Number of Transfers**
1	New	0.20	Single-Trip	0.50	0
2	New	0.20	Monthly	0.31	0
3	New	0.20	Quarterly	0.28	0
4	Loyal	0.10	Single-Trip	0.50	0
5	Loyal	0.10	Monthly	0.31	0
6	Loyal	0.10	Quarterly	0.28	0
7	New	0.20	Single-Trip	0.50	1
8	New	0.20	Monthly	0.31	1
9	Loyal	0.10	Single-Trip	0.50	1
10	Loyal	0.10	Monthly	0.31	1

Source: Own processing

The time spent waiting for the public transport vehicle, T_{wait}, was determined to be half the service interval. For Bus Line 19, which operates every 20 minutes, this value is 10 minutes. For Tram Line 2 (and 7, implied from previous text), the average waiting time is 7.5 minutes. Ten scenarios were created for the analysis (Table 3) to model various combinations of shared mobility and public transport trips. When calculating public transport costs, we accounted for three types of student tickets: single-use, monthly, and quarterly. For the monthly and quarterly passes, the cost of a single trip was calculated based on an estimated 40 trips per month, adjusted for working days. We assume that the student travels only for study purposes for 20 days per month, with each travel day including a journey to school and a return trip.

Subsequently, the Monte Carlo method was used to analyze the model agent's transport costs. For each of the 10 defined scenarios, 10,000 simulations were executed, employing a randomly selected combination of coefficients generated from the previously specified intervals (Harrison, 2010).

3 Results and Discussion

The Monte Carlo simulation estimated the distributions of total transport costs for e-scooters and public transport in each scenario. Figure 4's histograms show how the total costs for an e-scooter ride vary, depending on whether the rider was a new customer paying full price or a loyal customer with a discount. The x-axis displays the total simulated trip costs, while the y-axis indicates how often each cost occurred during the simulation.

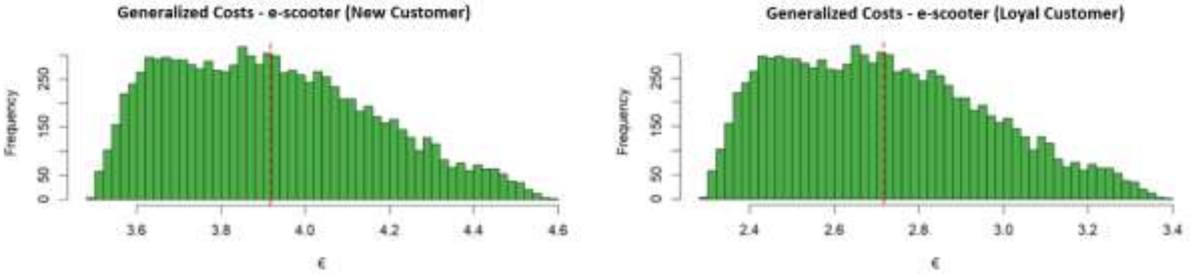

Figure 4 Simulation of Generalized Costs for an E-scooter Trip
Source: Own processing

Both histograms show similar distributions with a slight left skew. The x-axis shows costs in Euros, and the y-axis shows the frequency of those costs in the simulations. The red-dashed line in each histogram indicates the average total cost. For an e-scooter trip, the average Generalized Cost is €3.92 for a new customer and €2.72 for a loyal customer. This difference reflects the variation in per-minute rates for an average trip duration of 12 minutes. Notably, the half-price minute rate results in only a 30.6% reduction in total trip cost when considering all other simulated journey expenses.

For public transport, Figure 5 shows the distribution of simulated total costs for single-use, monthly, and quarterly tickets, specifically for the direct connection.

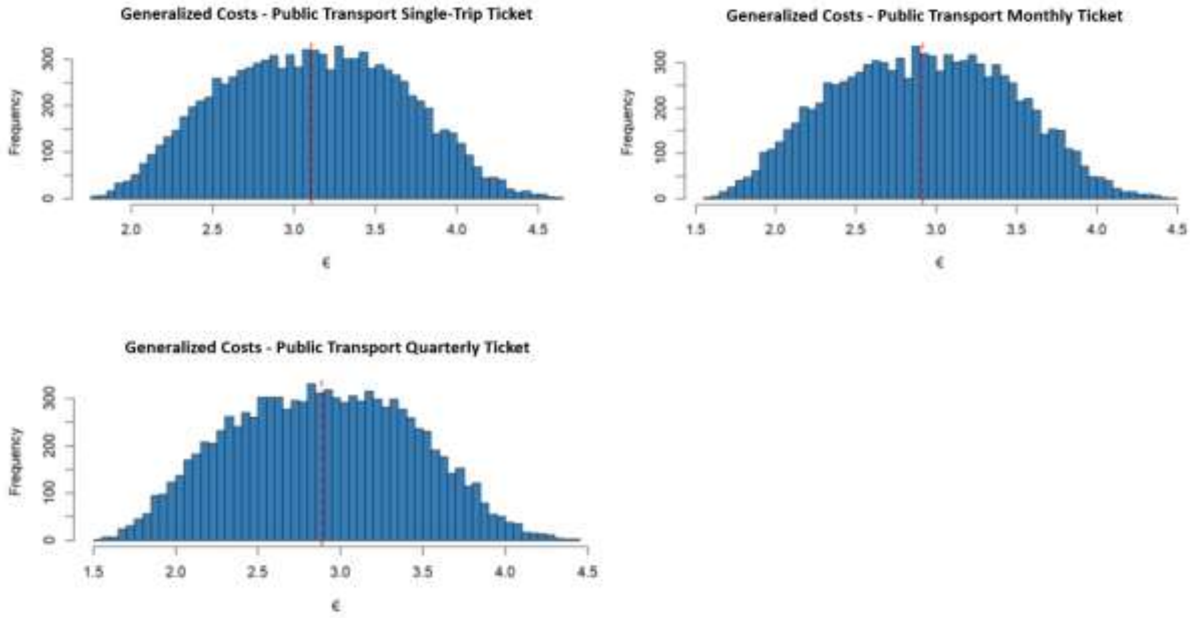

Figure 5 Simulation of Generalized Costs for Public Transport via a Direct Connection
Source: Own processing

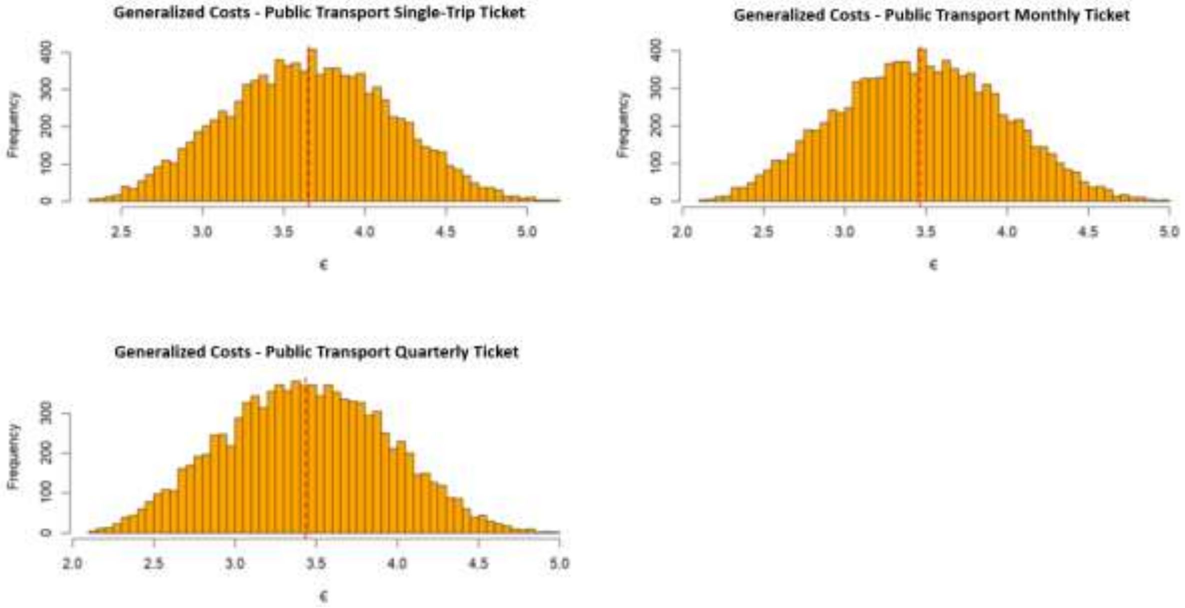

Figure 6 Simulation of Generalized Costs for Public Transport with a Transfer
Source: Own processing

Since the only variation among these three simulations is the ticket price, with all other costs being equal, the differences are minimal and directly reflect the prices listed in Table 3. The total Generalized Cost (GTC) for a direct connection is €3.11 for a single-use ticket, €2.95 for a monthly pass, and €2.89 for a quarterly pass. Including all factors in the trip's total cost shows that, although the ticket price savings are 40% for the monthly pass and 44% for the quarterly pass, the overall savings in Generalized Costs are only 5% and 7%, respectively. For journeys requiring one transfer (Figure 6), the transfer adds an extra cost (disutility), making the impact of ticket price differences on total trip costs even smaller – less than 5% for the monthly pass and 6% for the quarterly pass. The average GTCs were €3.66 for a single-use ticket, €3.47 for a monthly pass, and €3.44 for a quarterly pass.

Since the objective was to compare total trip costs across the different travel forms, simulations of all three alternatives were performed for the 10 selected scenarios.

Table 4 Parameters of Individual Scenarios

Scenario	**Antik Customer Status**	**Scooter Price (€/min)**	**Public Transport Ticket Type**	**Public Transport Ticket Cost (€/trip)**	**Number of Transfers**	**% of cases where the e-scooter is more advantageous**
1	New	0.20	Single-Trip	0.50	0	6.56%
2	New	0,20	Monthly	0.31	0	1.87%
3	New	0.20	Quarterly	0.28	0	1.45%
4	Loyal	0.10	Single-Trip	0.50	0	73.74%
5	Loyal	0.10	Monthly	0.31	0	62.14%
6	Loyal	0.10	Quarterly	0.28	0	60.25%
7	New	0.20	Single-Trip	0.50	1	30.79%
8	New	0.20	Monthly	0.31	1	19.15%
9	Loyal	0.10	Single-Trip	0.50	1	97.60%
10	Loyal	0.10	Monthly	0.31	1	93.58%

Source: Own processing

Table 4 presents the percentage of simulations in which the total Generalized Cost of e-scooter transport is lower than that of public transport across 10 scenarios. The e-scooter's per-minute rate significantly influences its relative advantage. In scenarios with a single-use public transport ticket without transfers (Scenarios 1 and 4), the proportion of cases favoring the e-scooter rises sharply – from 6.56% for new customers to 73.74% for loyal customers. Similar patterns are observed with monthly and quarterly passes. The cost of public transport also affects these outcomes: lower ticket prices reduce the frequency where the e-scooter is the cheaper option. Additionally, transfer requirements affect the comparison: transfers add disutility, increasing public transport's total GTC and thus making the e-scooter more appealing. The smallest advantage for the e-scooter appears in Scenario 3 (1.45%), involving a new Antik customer and the cheapest public transport ticket without transfer; the most significant advantage is in Scenario 9 (97.6%), involving a loyal customer, a pricier ticket, and a transfer.

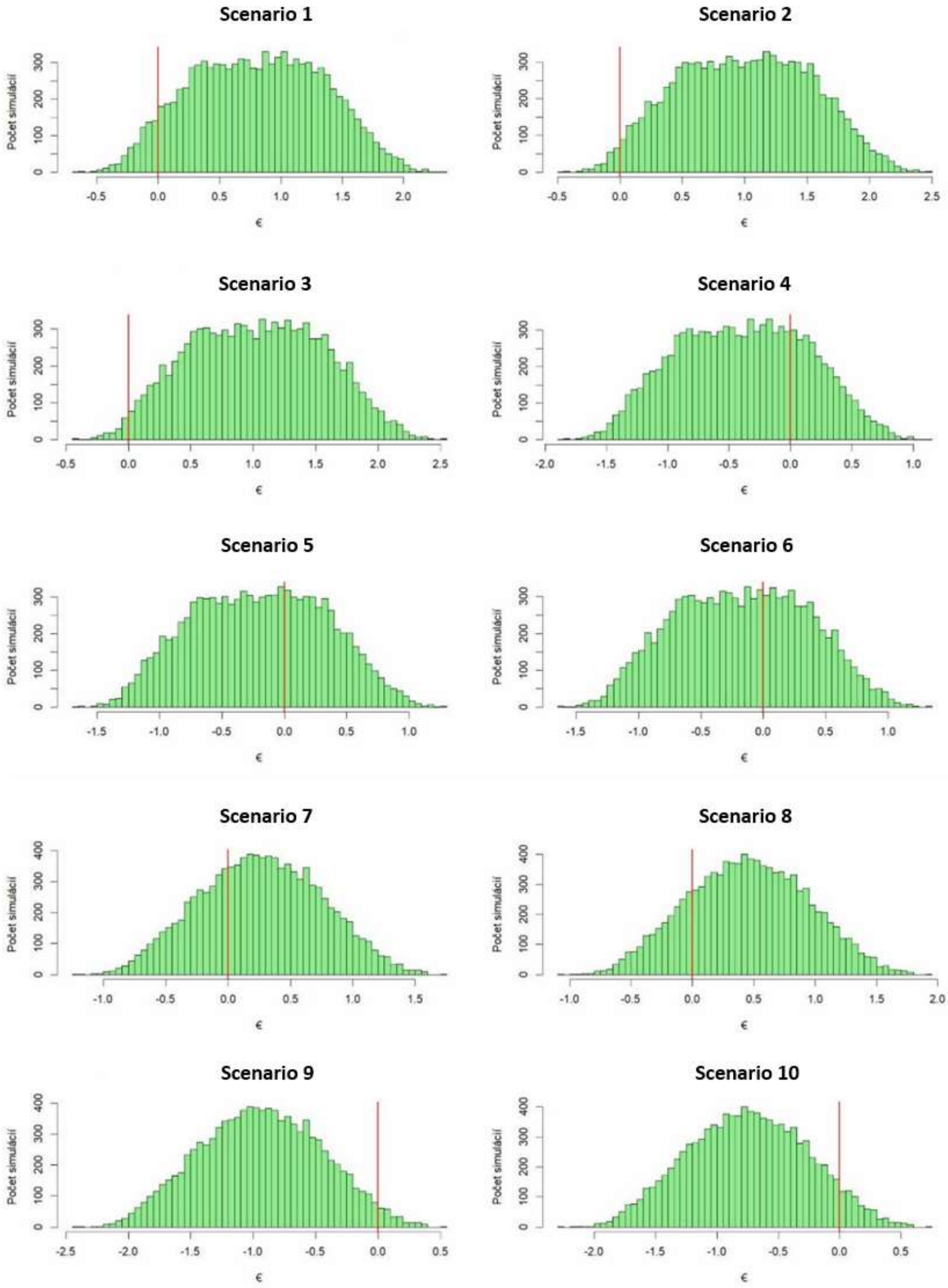

Figure 7 Comparison of Simulated Generalized Trip Costs for Shared Micromobility and Public Transport for Selected Scenarios
Source: Own processing

Figure 7 illustrates how the total cost differences between e-scooters and public transport vary across the 10 scenarios. Positive values on the x-axis indicate cases where e-scooter trip costs exceed those of public transport. These scenarios help us understand the impact of ride and ticket price differences, as well as how total perceived costs are affected by both time considerations and travel comfort factors.

Our Monte Carlo simulation results on the competition between shared e-scooters and public transport closely match the findings of international studies, including Kalakoni et al. (2024), which examined this relationship in France. The study shows that e-scooters are generally more time-efficient and preferred for short trips, especially those up to 15 minutes. Our route (2.3 km, with an estimated scooter time of 12 minutes) falls within this range, which explains the observed competition across our 10 scenarios. Similar to our analysis, which considers time costs and transfer disutility, the French research highlights that e-scooters are more beneficial during periods with lower MHD service frequency or in areas with limited connectivity, leading to higher Generalized Costs for public transport. Our findings also confirm that transfer-related issues, as in Scenario 9, significantly raise the public transport GTC, giving e-scooters an edge.

While Kalakoni et al. (2024) suggest that travelers choose e-scooters despite a price premium in exchange for time savings, our simulation provides a detailed perspective on the impact of local loyalty programs. We demonstrated that a half-price discount for a loyal customer almost eliminates this price premium, making the e-scooter more advantageous in up to 97.6% of simulations when public transport travel is inconvenient (with a transfer). This highlights that micromobility operators' targeted pricing policy is a decisive factor that can dramatically alter transport competitiveness on short urban routes.

For trips that go beyond the typical range of shared micromobility, usually 3 to 5 km or about 15 minute, the advantages of the e-scooter diminish quickly. This is mainly due to its limited range, discomfort, and exposure to weather conditions. Public transportation remains the preferred choice for longer distances because of its higher speed, capacity, and protection from the weather, which helps reduce the time and inconvenience that contribute to higher Generalized Costs over short distances. As a result, shared micromobility plays a supportive role on longer routes, mainly serving as the "first and last mile" solution, thereby improving the accessibility and appeal of public transport.

According to the Generalized Cost analysis, shared e-scooter operators should adopt a differential pricing strategy that capitalizes on customer loyalty and the inconvenience associated with public transport. For loyal customers on short-to-medium routes (5-15 minutes), maintaining a low per-minute rate (€0.10/min) is essential to maximize market share, as this group highly values time savings and avoiding the inconveniences of public transit, such as transfers and waiting times. New customers, on the other hand, require promotional offers to overcome the high entry cost caused by the standard €0.20/min rate. Additionally, operators should promote intermodality by offering fixed, low-cost options for first- and last-mile trips near transit stations and by encouraging the combined use of scooters and public transport, thereby enhancing urban mobility and accessibility.

This study primarily examines Generalized Travel Costs for shared micromobility and public transport, focusing on economic factors and perceived comfort. However, it is important to place these results within the larger body of scientific research. Shared micromobility offers advantages beyond saving time and money, including non-financial benefits in four key areas: environmental sustainability, social equity, health and psychological well-being, and urban resilience. A comprehensive review highlights that the overall usefulness of shared micromobility depends on active municipal regulation and infrastructure investments, rather than being an inherent trait.

Shared micromobility's environmental impact, especially its role in reducing greenhouse gas emissions, is vital. Yet, research like Krauss et al. (2022), using Life Cycle Assessment, shows a "substitution trade-off" that limits this benefit. In some cities, shared scooters replace up to 49% of trips that would have been made by walking or public transit. This shift away from the most eco-friendly options diminishes overall benefits, so genuine sustainability requires measures that prioritize replacing individual motorized trips.

Similarly, the social aspect is emphasized. While shared micromobility can enhance overall accessibility, especially by solving first- and last-mile challenges, the absence of proper regulation might worsen existing spatial inequalities in transport access. Gao & Li (2024) found that the greatest gains in equity and passenger satisfaction come from integrating these services with public transport, which should be a key policy goal. Local transport companies are often hesitant to serve the shared micromobility sector mainly due to concerns about economic inefficiency and the risk of cannibalizing existing fixed-route services (Pinski et al., 2026; Deschaintres et al., 2025). Running flexible, on-demand services like microtransit typically costs more per passenger than traditional fixed-route buses, and these costs don't decrease with scale because additional drivers and vehicles are needed linearly (Pinski et al., 2026). Moreover, transport agencies worry that shared modes might compete directly with established routes, especially in city centers during peak hours, where they can provide faster, more direct trips without transfers (Deschaintres et al., 2025). Without careful strategic planning, passengers might prefer shared services for entire trips, draining resources from public transit, lowering overall ridership, and possibly increasing traffic congestion paradoxically (Lau & Susilawati, 2021; Pinski et al., 2026). This uncertainty about revenue impact and operational stability poses a major barrier to fully integrating micromobility into public transport systems (Pinski et al., 2026).

Finally, psychological benefits and urban network resilience are key factors shaping perceptions of travel utility, as reflected in the GTC model over time and in the disutility variables. Dias et al. (2021) demonstrated that shared micromobility functions as an urban resilience asset, offering a dependable, socially distanced alternative during crises such as COVID-19, thereby supporting the stability of vital urban functions. These results indicate that non-financial benefits are crucial in mode choice, highlighting the significance of comfort and reliability within the GTC framework.

Despite the insights gained from quantifying travel costs, this study has several methodological limitations that open avenues for future research. As previously mentioned, our GTC model mainly considers individual user costs and does not account for broader negative externalities, such as the social costs of spatial disorder or the environmental burdens associated with Li-ion batteries during their lifecycle, which is a notable scope limitation. Additionally, the model operates within a current market context marked by institutional asymmetry, where subsidized public transit competes with private platforms that may use unpredictable price-dumping strategies. Because these pricing dynamics are expected to undergo significant structural changes as the sector develops, the current simulation's static nature may not accurately reflect long-term market equilibrium. Consequently, future research should incorporate longitudinal data and more detailed institutional analysis within a Mobility-as-a-Service (MaaS) framework to better understand the changing transportation landscape and facilitate more comprehensive management of social and environmental externalities.

Conclusion

In conclusion, the Monte Carlo simulation effectively quantified the competitive dynamics between shared e-scooters and public transport in Košice's urban environment, with results aligning closely with international studies. Our research confirms that for short-to-medium distances (under 15 minutes or 3–5 km), e-scooters pose a considerable competitive threat, mainly because of their faster travel times and greater convenience, which significantly lower the user's Generalized Cost. Importantly, the analysis underscored the strong influence of targeted loyalty pricing: a half-price discount for loyal customers can offset the economic advantage of public transport in most cases, leading to e-scooter dominance in up to 97.6% of simulations when public transport includes high disutility factors, such as transfers. Conversely, on longer routes, the relationship becomes more complementary, with e-scooters addressing the first- and last-mile challenge to improve access to public transit. The study thus recommends that urban policymakers and micromobility providers develop strategies that account for actual time costs and disutility in GTC calculations. By adjusting pricing policies to encourage usage on short, competitive routes and promoting intermodality near transit hubs, cities can better integrate these modes, creating a more flexible, efficient, and sustainable transportation system.

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