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MICROMOBILITY REVOLUTION: RECOMMENDING EFFICIENT RESTAURANT DELIVERY SYSTEMS IN HUNGARY AND KYRGYZSTAN

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Abstract: *The transportation systems of modern cities face growing challenges due to increasing populations and urbanization, resulting in reduced efficiency, heightened air pollution, and significant environmental strain. Micromobility solutions, such as electric bicycles and scooters, have emerged as effective and sustainable alternatives, offering reduced emissions and promoting the efficient use of resources. This study expands on the concept and applications of micromobility, particularly its role in logistics, with a focus on the "last mile" concept. This critical segment of the logistics chain emphasizes optimizing the final phase of delivery processes, illustrated here through a route planning analysis from the perspective of a fast-food delivery courier, incorporating the consolidation of purchasing and utility costs for various delivery methods. To deepen the understanding of micromobility's impact, this research includes a comparative case study conducted in Miskolc, Hungary, and Bishkek, Kyrgyzstan. The analysis examines the distinct urban contexts of these cities, assessing the efficiency, environmental benefits, and practical applications of micromobility solutions in their respective restaurant delivery ecosystems.*

Keywords: *micromobility, last-mile logistics, urban delivery systems; international case study*

1. INTRODUCTION

Micromobility plays a crucial role in modern urban life, offering efficient and sustainable transportation options. It has a significant impact on last-mile logistics, addressing the challenge of delivering goods and services quickly in congested areas. For instance, food delivery couriers often rely on bicycles or electric scooters to navigate traffic and reach customers efficiently. These small-scale vehicles not only reduce delivery times but also minimize the environmental footprint. As cities grow, micromobility will continue to be a key solution for both personal transport and logistics needs.

Micromobility is a highly interdisciplinary and extensively researched field, integrating perspectives from transportation engineering, economics, sociology, and environmental sciences. Studies examine various aspects, including the environmental impacts, economic benefits, and effects on transportation systems, as well as social inequities related to access and usage. Additionally, the impact of micromobility on health and urban quality of life is continually explored. Within the frame of this chapter, the main research directions are summarized focusing on air quality, financial incentives, safety and injury severity, environmental impact, use acceptance, policies and regulation, and demographic factors.

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Air quality alerts alone are insufficient to change transportation behaviours without broader societal awareness and access to sustainable alternatives. A research by Xu et al. shows that despite the presence of air quality alerts, micromobility and driving behaviours remained largely unchanged, as evidenced by the analysis of millions of trips and traffic counts [1]. While there was a reduction in usage during polluted daytime periods, this was likely due to the immediate air conditions rather than the alerts themselves. The findings emphasize the role of social context factors, such as societal attention to air quality and the availability of sustainable transport, in enabling meaningful behavioural shifts.

Financial incentives play a crucial role in boosting the adoption and profitability of shared micromobility systems. Research works by Fuady et al., highlights that strategies such as fee reductions and government subsidies significantly enhance user adoption and the economic viability of micromobility systems [2]. Conversely, increased operational fees require careful management to avoid undermining service attractiveness. These findings, derived from system dynamics modelling and policy scenario analyses, underline the importance of financial measures in fostering sustainable urban transportation solutions.

Bicycles and personal mobility devices (PMD) experience similar collision scenarios, but differences in injury severity indicate the need for distinct safety measures for each. A study by Guesneau et al. shows that the most frequent and severe collision scenario for both bicycles and PMDs is side-on-head collisions with cars, accounting for 51% and 58% of cases, respectively. Despite these similarities, bicycles have a higher risk of severe injury compared to PMDs, even after adjusting for factors like vehicle size, rider age, and road speed limits. These findings underline the importance of treating bicycles and PMDs as separate categories in crash investigations to tailor protective measures effectively.

A significant portion of private car trips can be replaced by micromobility, leading to notable environmental benefits. A study by Comi and Polimeni identifies that 31% of daily car round trips in the city of Trani could be substituted by micromobility, based on an analysis of floating car data (FCD) that characterized trip features [4]. This shift could result in a reduction of traffic emissions by over 21% from private cars, highlighting the potential of micromobility to improve urban sustainability and reduce environmental impact. The parametric methodology developed is adaptable to other cities, making it a valuable tool for urban mobility planning and the promotion of sustainable transport solutions.

Shared e-scooters (SES) have limited positive environmental impacts, as most trips replace low-emission modes such as walking or public transport. Gao et al. in their study reveals that over 85% of SES trips in Swedish cities replace walking or public transport, with less than 12% substituting private cars or taxis [5]. On average, each SES trip increases CO_2 emissions, with only a small fraction of trips (around 19–24%) and urban areas (2–8%) showing positive environmental effects. These findings highlight the need for trip-level analyses to better understand SES impacts and inform sustainable urban mobility strategies.

Social influence, performance expectancy, and hedonic motivation are key psychological drivers of user acceptance for electric micromobility-sharing services (EMS), while personality traits like openness and extraversion have weaker effects. The study written by Xie and Liao employs structural equation modelling to analyse EMS adoption and identifies three factors: social influence, performance expectancy, and hedonic motivation [6]. These factors have the strongest positive effects on user acceptance. Among personality traits, openness and extraversion contribute weakly, while others show no significant impact. These findings highlight the importance of psychological and demographic factors in shaping tailored EMS deployment strategies.

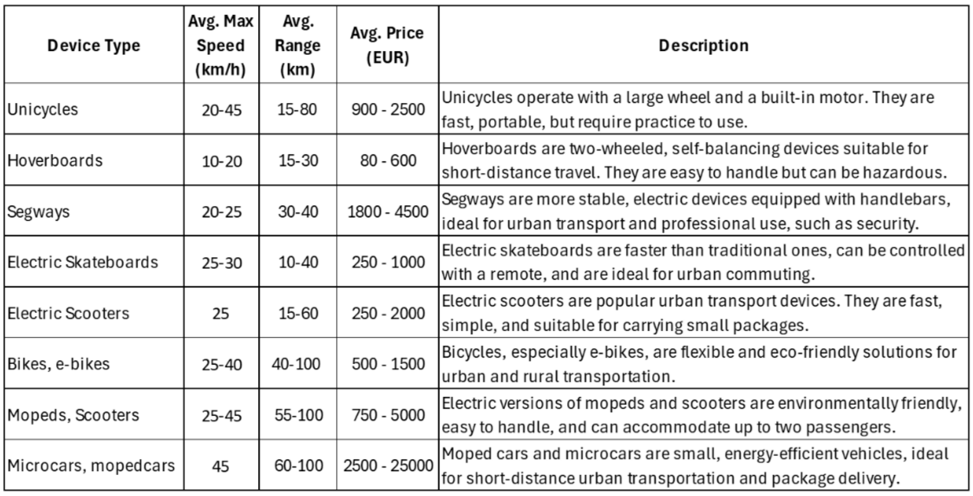
Shared micromobility can improve overall, but it amplifies spatial inequities, requiring targeted regulatory policies for equitable benefits. Gao and Li finds, that while shared micromobility enhances transport accessibility, its benefits are unevenly distributed across geographic zones, increasing spatial inequity gaps [7]. Among the policies evaluated, transit-micromobility collaboration emerges as the most effective approach, achieving higher equity improvements, enhancing passenger surplus, and maintaining platform profitability. Other policies, like minimum vehicle density requirements and ride subsidies, offer some benefits but have limitations in either equity improvement or economic feasibility, as demonstrated in a case study of San Francisco.

Active transport offers significant economic benefits, particularly through health improvements, but data for electric micromobility remains limited and inconsistent. A review by Del Rosario et al. found wide-ranging economic values for walking (USD −0.25 to 4.25/km), cycling (USD −1.00 to 1.95/km), and electric modes (USD −0.44 to 1.15/km), with health benefits dominating active transport [8]. However, evidence for electric micromobility benefits is inconsistent, with gaps in data and varying quality in grey literature. These findings highlight the need for robust, comprehensive research to guide investments in these modes.

Demographic factors and land use patterns significantly influence micromobility ridership, with younger populations and urban areas showing higher usage. The study written by Jafarzadehfadaki et al. [9] found that micromobility usage peaks in high-density areas such as parks and university campuses, with younger people (18-34 years) showing higher ridership, while older individuals (45-54 years) used it less [9].

Table I.

Summary of Electric Micromobility Devices



Device Type	Avg. Max Speed (km/h)	Avg. Range (km)	Avg. Price (EUR)	Description
Unicycles	20-45	15-80	900 - 2500	Unicycles operate with a large wheel and a built-in motor. They are fast, portable, but require practice to use.
Hoverboards	10-20	15-30	80 - 600	Hoverboards are two-wheeled, self-balancing devices suitable for short-distance travel. They are easy to handle but can be hazardous.
Segways	20-25	30-40	1800 - 4500	Segways are more stable, electric devices equipped with handlebars, ideal for urban transport and professional use, such as security.
Electric Skateboards	25-30	10-40	250 - 1000	Electric skateboards are faster than traditional ones, can be controlled with a remote, and are ideal for urban commuting.
Electric Scooters	25	15-60	250 - 2000	Electric scooters are popular urban transport devices. They are fast, simple, and suitable for carrying small packages.
Bikes, e-bikes	25-40	40-100	500 - 1500	Bicycles, especially e-bikes, are flexible and eco-friendly solutions for urban and rural transportation.
Mopeds, Scooters	25-45	55-100	750 - 5000	Electric versions of mopeds and scooters are environmentally friendly, easy to handle, and can accommodate up to two passengers.
Microcars, mopedcars	45	60-100	2500 - 25000	Moped cars and microcars are small, energy-efficient vehicles, ideal for short-distance urban transportation and package delivery.

E-scooter sharing services disproportionately affect disadvantaged populations, with minority and low-income groups facing limited access and longer waiting times. The research study by Bai and Jiao found that nearly all minority populations in Austin had fewer opportunities to use E-scooters, with 10% experiencing longer wait times for disturbances to be resolved [10]. Additionally, low-income individuals were disadvantaged by high availability but moderate burdens, while physically disabled individuals faced higher burdens.

Table I. summarizes commonly used electric vehicles for last-mile logistics and personal transport. It compares micromobility options like unicycles, hoverboards, and electric scooters based on speed, range, price, and use. The data highlights their potential for eco-friendly, short-distance transportation in various settings [11].

The rapid proliferation of micromobility devices raises specific regulatory challenges, as they do not fit neatly into existing transportation categories. Developing road safety regulations and urban infrastructure is crucial to ensure their safe operation. Overall, micromobility represents a new direction in urban transportation, making short-distance travel not only more sustainable but also more flexible. These devices play a pivotal role in the future of smart cities, which is why we are examining their potential to professionally include them in last mile logistics as a part as the restaurant delivery system.

2. ROUTE PLANNING IN DELIVERY SYSTEMS

Route planning plays a fundamental role in designing and managing material flow systems, particularly in urban transportation and micromobility A well-crafted route plan enhances efficiency, reduces energy consumption, and minimizes environmental impact. Factors like material flow characteristics, product volume, delivery locations, and vehicle parameters significantly influence route planning, aiming to minimize costs, time, and energy use [12].

Route types – such as line routes, circular routes, or mixed routes – must address specific needs, with optimization focusing on maximizing vehicle capacity and minimizing empty trips. The “last mile” of logistics, the most critical supply chain phase, often incurs high costs and environmental impact, mitigated by new technologies like electric vehicles and drones [13].

In recent years, urban micromobility, including shared e-bikes and scooters, has provided fast, eco-friendly alternatives for couriers. These vehicles, equipped with GPS, improve route tracking, reduce accidents via bike lanes, and support sustainable transport. Shared micromobility options also lower delivery costs, eliminate parking issues, and optimize efficiency, benefiting both couriers and urban transportation [14].

Route planning is also crucial in modern urban environments, especially for deliveries to multiple locations within a limited timeframe. For example, pizza couriers may need to deliver to over a hundred addresses in a single day, making it essential to determine the shortest and most efficient routes. Algorithms like the Traveling Salesman Problem (TSP) are commonly used to optimize the delivery order [15].

Vehicle fleet composition is another key factor, with bicycle delivery services using various vehicles like cars, scooters, and bicycles. Sustainable options such as e-scooters and e-bikes are increasingly preferred to reduce emissions and operational costs [16].

This study was created by analysing pizzerias in Miskolc and Bishkek to recreate delivery routes for 60 addresses across the cities, with more deliveries grouped by urban districts like city centre, campus/college sites, high density living areas, etc.

By optimizing route planning, the study demonstrated improved courier efficiency and reduced time and costs. Comparisons between cars and micromobility devices highlighted the advantages of e-scooters and e-bikes in urban settings. Shared micromobility solutions offered economic benefits by lowering parking challenges and operational expenses while supporting environmental sustainability. These findings underscore how modern technologies and optimization methods can enhance urban delivery processes.

During route planning, one of the initial steps is defining the route matrix or graph. A complete route matrix for 60 elements would require data from 3,600 map queries, and even when segmented into groups (distance, duration, max delivery points, max quantity), it would still involve hundreds of queries. Therefore, we opted for a simpler solution. Using the Haversine formula, we calculated straight-line distances and compared them in some cases to actual map data for both Miskolc and Bishkek. As observed in Table 2, basically the same multiplier emerged between 1,4-1,5. This similarity can be attributed to the fact that both are large cities with comparable structures. According to Table II, we use the Haversine-calculated distances in our case study with a multiplier of 1.45 to account for the difference between straight-line distances and actual transport routes on a map.

Table II.

Distance between addresses in Miskolc and Bishkek according to calculations and maps

	Miskolc					Bishkek				
	Lattitude	Longitude	Calculated distance (km)	Measured distance (km)	Multiplier	Lattitude	Longitude	Calculated distance (km)	Measured distance (km)	Multiplier
Pizza place	48,102509	20,786759	-	-	-	42,872491	74,615375	-	-	-
1	48,100755	20,754789	2,38	2,70	1,13	42,849369	74,587189	3,45	5,00	1,45
2	48,104288	20,808172	1,60	1,80	1,12	42,824726	74,573911	6,30	8,50	1,35
3	48,10777	20,787861	0,59	1,00	1,69	42,854792	74,590221	2,84	4,40	1,55
4	48,103143	20,753609	2,46	3,00	1,22	42,87025	74,614455	0,26	0,25	0,96
5	48,086807	20,739205	3,94	6,10	1,55	42,829834	74,589280	5,20	6,80	1,31
6	48,076038	20,776563	3,04	3,80	1,25	42,868610	74,643212	2,31	5,40	2,34
7	48,100474	20,693123	6,96	8,00	1,15	42,845767	74,648763	4,03	7,30	1,81
8	48,090334	20,776088	1,57	2,60	1,66	42,867444	74,606202	0,93	1,40	1,50
9	48,110005	20,769322	1,54	2,10	1,36	42,853388	74,557007	5,21	7,10	1,36
10	48,105867	20,681727	7,81	9,00	1,15	42,879545	74,548840	5,48	6,70	1,22
11	48,094102	20,778483	1,12	1,70	1,52	42,882195	74,583893	2,78	3,70	1,33
12	48,107513	20,677029	8,17	9,40	1,15	42,893288	74,597860	2,72	3,90	1,44
13	48,092891	20,789233	1,09	1,60	1,47	42,892848	74,598527	2,65	3,80	1,44
14	48,073773	20,829518	4,51	5,40	1,20	42,882740	74,626181	1,44	2,20	1,53
15	48,090163	20,782869	1,40	1,80	1,28	42,834347	74,567232	5,78	9,00	1,56
16	48,101613	20,786224	0,11	0,35	3,26	42,835358	74,588941	4,66	6,50	1,40
17	48,089982	20,70886	5,95	8,00	1,34	42,878519	74,631651	1,49	2,80	1,88
18	48,103106	20,756401	2,26	2,70	1,20	42,837437	74,59974	4,10	5,10	1,24
19	48,068352	20,787252	3,80	4,50	1,18	42,832963	74,639945	4,83	6,90	1,43
20	48,102613	20,735573	3,80	4,70	1,24	42,885192	74,569017	4,03	5,20	1,29
Avg.			3,20	4,01	1,41			3,52	5,10	1,47

However, Miskolc is a city with a population of around 145,000, covering an area of 236 km², of which 54 km² is urban. Bishkek, on the other hand, is the capital of Kyrgyzstan with a population of 1,140,000 and an area of 127 km². Unfortunately, there is no specific data on the breakdown between urban and suburban areas in Bishkek. Comparing the two cities, the delivery routes in Bishkek are approximately 1.5 times longer overall in any direction due to the larger population and urban density. This factor is slightly offset by the higher number of restaurants in Bishkek, which better distribute delivery areas, and the preference of residents to order from closer locations. As a result, we adjusted the travel distance multiplier for

Bishkek to 1.25. This is further supported by the difference in average distances between the two cities is measured distances, as shown in Table II.

This was followed by group segmentation. While much could be written about this process due to the many challenges and decisions involved, we aim to keep it concise for the format and focus of the article. Delivery groups were defined in the simplest and most practical way possible, allowing easy implementation in a restaurant setting. Instead of full optimization, also known as combined grouping and route planning—which would require excessive computational resources—we applied a “group first, then plan routes within” method. This approach is much more practical given the real-world constraints:

- Orders should be delivered following an almost FIFO (First In, First Out) principle, allowing for some flexibility and mixing.
- Orders should ideally arrive within 1.5 hours of being placed.
- Except for cars, all delivery vehicles can carry only one pizza backpack, with a maximum capacity of 8 pizzas.
- Different vehicles operate at different speeds, so exceeding a certain quantity makes it impossible to deliver to multiple locations.
- For electric vehicles, charging time must be considered, requiring the use of alternative vehicles during recharge periods.

The optimization for each group was performed using Excel's built-in Solver add-in.

The first group consisted of orders received between 11:25 and 12:12, which were completed by 12:23, with exactly 8 pizzas. Subsequent groups were formed similarly, as shown in Table III. Afterward, we created another grouping, focusing solely on time, as car deliveries can handle more than 8 pizzas at once. Here, we ensured that within a 1-hour time interval, there were no more than 7 addresses, since the pickup time per address takes at least 3 minutes when planning routes. A comparison of the two tables shows that when using micromobility tools (scooters, bicycles, mopeds), more groups need to be formed due to the limitation of delivery bags designed for 8 pizzas. However, car deliveries can accommodate up to 13 pizzas at a time. After creating the groups, we also analysed the distances between the addresses.

Additionally, we examined how many additional couriers would be needed to deliver the remaining orders if the courier adhered to the specified route time under the current grouping. For this, we recorded the time associated with the travel distances in Excel, broken down by vehicle type: car, scooter, bicycle, and electric scooter. Based on our observations of urban traffic, we concluded that scooters are approximately 20% faster than cars, while bicycles are 20% faster than electric scooters. Using this data, we created the following table.

From the analysis of the time data, we determined that for the first group, a courier using a car departs at 12:23 and returns at 13:47. Among micromobility tools, only a scooter can complete the delivery, with the courier departing at 12:23 and returning by 13:30. Based on the group divisions (Table III), another courier would have to depart during this time frame, making it clear that at least two couriers are necessary.

For bicycle and electric scooter delivery, we reexamined the route plan to serve 6 addresses. By reassigning the seventh address, we reduced the route time to under 90 minutes for bicycles; however, for electric scooters, the time still exceeded the limit by 22 minutes.

Our analysis indicates that for this group, electric scooter delivery can only handle the first three addresses. Further examination of the time data shows that for bicycle and electric scooter delivery, more than two couriers are required to fulfil the orders within the given time frame.

For the route planning of subsequent groups, we followed the previously described steps.

Table III.

Delivery groups (colours) by bicycle (left) and car (right)

#	Order Time	Start of Preparation	Placed in Oven	Ready for delivery	Time from Order	Coordinates	Order quantitiy
1.	11:25	11:25	11:32	11:36	0:11	48.100755, 20.754789	1
2.	11:30	11:32	11:39	11:43	0:13	48.104288, 20.808172	1
3.	11:44	11:44	11:51	11:55	0:11	48.107770, 20.787861	1
4.	11:45	11:51	11:54	11:58	0:13	48.103143, 20.753609	1
5.	11:52	11:54	11:58	12:02	0:10	48.086807, 20.739205	1
6.	12:00	12:00	12:07	12:11	0:11	48.076038, 20.776563	1
7.	12:12	12:12	12:19	12:23	0:11	48.100474, 20.693123	2
8.	12:20	12:20	12:27	12:31	0:11	48.090334, 20.776088	2
9.	12:24	12:27	12:34	12:38	0:14	48.110005, 20.769322	2
10.	12:32	12:34	12:39	12:43	0:11	48.105867, 20.681727	1
11.	12:34	12:39	12:42	12:46	0:12	48.094102, 20.778483	1
12.	12:45	12:45	12:52	12:56	0:11	48.107513, 20.677029	1
13.	13:00	13:00	13:07	13:11	0:11	48.092891, 20.789233	2
14.	13:05	13:07	13:14	13:18	0:13	48.073773, 20.829518	1
15.	13:10	13:14	13:21	13:25	0:15	48.090163, 20.782869	2
16.	13:12	13:21	13:35	13:39	0:27	48.101613, 20.786224	1
17.	13:22	13:35	13:49	13:53	0:31	48.089982, 20.708860	7
18.	13:26	13:49	13:56	14:00	0:34	48.103106, 20.756401	1
19.	13:32	13:56	14:03	14:07	0:35	48.068352, 20.787252	2
20.	13:52	14:03	14:10	14:14	0:22	48.102613, 20.735573	2
21.	14:02	14:10	14:17	14:21	0:19	48.068159, 20.744438	2
22.	14:05	14:17	14:20	14:24	0:19	48.103330, 20.786910	1
23.	14:08	14:20	14:24	14:28	0:20	48.106860, 20.772896	1
24.	14:10	14:24	14:31	14:35	0:25	48.072015, 20.782204	1
25.	14:40	14:40	14:47	14:51	0:11	48.079177, 20.777383	1
26.	14:45	14:47	14:54	14:58	0:13	48.078521, 20.721896	2
27.	14:52	14:54	15:01	15:05	0:13	48.067223, 20.748881	1
28.	15:02	15:02	15:09	15:13	0:11	48.066455, 20.778854	2
29.	15:06	15:09	15:16	15:20	0:14	48.090564, 20.793635	2
30.	15:20	15:20	15:27	15:31	0:11	48.105129, 20.768545	1
31.	15:22	15:27	15:34	15:38	0:16	48.092416, 20.813195	1
32.	16:04	16:04	16:18	16:22	0:18	48.115175, 20.792398	2
33.	16:32	16:32	16:39	16:43	0:11	48.104777, 20.674490	1
34.	16:55	16:55	17:02	17:06	0:11	48.080223, 20.721061	2
35.	17:00	17:02	17:09	17:13	0:13	48.091939, 20.770392	1
36.	17:05	17:09	17:16	17:20	0:15	48.104935, 20.740534	1
37.	17:23	17:23	17:30	17:34	0:11	48.101846, 20.710331	1
38.	17:24	17:30	17:33	17:37	0:13	48.081587, 20.769546	1
39.	17:25	17:33	17:37	17:41	0:16	48.108009, 20.790945	1
40.	17:30	17:37	17:44	17:48	0:18	48.056097, 20.756928	1
41.	17:44	17:44	17:51	17:55	0:11	48.072831, 20.770451	1
42.	17:55	17:55	18:05	18:09	0:14	48.094831, 20.769954	3
43.	17:55	18:05	18:12	18:16	0:21	48.097037, 20.707767	2
44.	18:02	18:12	18:19	18:23	0:21	48.119362, 20.786367	2
45.	18:10	18:19	18:26	18:30	0:20	48.082859, 20.776438	2
46.	18:17	18:26	18:33	18:37	0:20	48.090858, 20.803443	1
47.	19:01	19:01	19:08	19:12	0:11	48.073979, 20.782634	1
48.	19:04	19:08	19:15	19:19	0:15	48.103352, 20.726441	1
49.	19:30	19:30	19:37	19:41	0:11	48.100536, 20.789361	1
50.	19:33	19:37	19:44	19:48	0:15	48.101906, 20.782653	1
51.	20:00	20:00	20:07	20:11	0:11	48.086240, 20.787318	1
52.	20:02	20:07	20:14	20:18	0:16	48.101168, 20.805454	1
53.	20:05	20:14	20:21	20:25	0:20	48.102236, 20.718332	2
54.	20:08	20:21	20:28	20:32	0:24	48.102426, 20.780732	2
55.	20:12	20:28	20:31	20:35	0:23	48.079875, 20.770089	1
56.	20:15	20:31	20:38	20:42	0:27	48.102836, 20.779172	1
57.	20:22	20:38	20:45	20:49	0:27	48.101442, 20.792967	2
58.	20:25	20:45	20:52	20:56	0:31	48.089784, 20.725582	2
59.	20:33	20:52	20:59	21:03	0:30	48.068804, 20.827343	2
60.	20:50	20:59	21:03	21:07	0:17	48.101660, 20.789066	2

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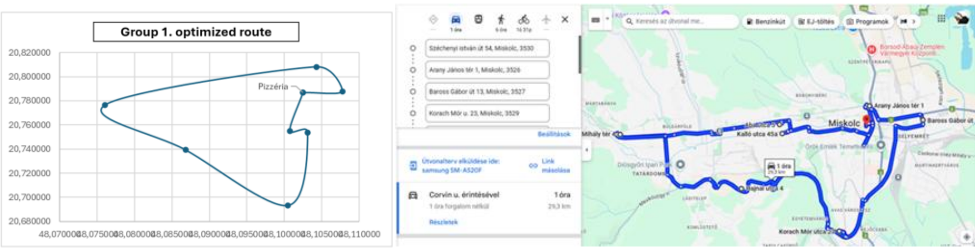
3.	11:44	11:44	11:51	11:55	0:11	48.107770, 20.787861	1
4.	11:45	11:51	11:54	11:58	0:13	48.103143, 20.753609	1
5.	11:52	11:54	11:58	12:02	0:10	48.086807, 20.739205	1
6.	12:00	12:00	12:07	12:11	0:11	48.076038, 20.776563	1
7.	12:12	12:12	12:19	12:23	0:11	48.100474, 20.693123	2
8.	12:20	12:20	12:27	12:31	0:11	48.090334, 20.776088	2
9.	12:24	12:27	12:34	12:38	0:14	48.110005, 20.769322	2
10.	12:32	12:34	12:39	12:43	0:11	48.105867, 20.681727	1
11.	12:34	12:39	12:42	12:46	0:12	48.094102, 20.778483	1
12.	12:45	12:45	12:52	12:56	0:11	48.107513, 20.677029	1
13.	13:00	13:00	13:07	13:11	0:11	48.092891, 20.789233	2
14.	13:05	13:07	13:14	13:18	0:13	48.073773, 20.829518	1
15.	13:10	13:14	13:21	13:25	0:15	48.090163, 20.782869	2
16.	13:12	13:21	13:35	13:39	0:27	48.101613, 20.786224	1
17.	13:22	13:35	13:49	13:53	0:31	48.089982, 20.708860	7
18.	13:26	13:49	13:56	14:00	0:34	48.103106, 20.756401	1
19.	13:32	13:56	14:03	14:07	0:35	48.068352, 20.787252	2
20.	13:52	14:03	14:10	14:14	0:22	48.102613, 20.735573	2
21.	14:02	14:10	14:17	14:21	0:19	48.068159, 20.744438	2
22.	14:05	14:17	14:20	14:24	0:19	48.103330, 20.786910	1
23.	14:08	14:20	14:24	14:28	0:20	48.106860, 20.772896	1
24.	14:10	14:24	14:31	14:35	0:25	48.072015, 20.782204	1
25.	14:40	14:40	14:47	14:51	0:11	48.079177, 20.777383	1
26.	14:45	14:47	14:54	14:58	0:13	48.078521, 20.721896	2
27.	14:52	14:54	15:01	15:05	0:13	48.067223, 20.748881	1
28.	15:02	15:02	15:09	15:13	0:11	48.066455, 20.778854	2
29.	15:06	15:09	15:16	15:20	0:14	48.090564, 20.793635	2
30.	15:20	15:20	15:27	15:31	0:11	48.105129, 20.768545	1
31.	15:22	15:27	15:34	15:38	0:16	48.092416, 20.813195	1
32.	16:04	16:04	16:18	16:22	0:18	48.115175, 20.792398	2
33.	16:32	16:32	16:39	16:43	0:11	48.104777, 20.674490	1
34.	16:55	16:55	17:02	17:06	0:11	48.080223, 20.721061	2
35.	17:00	17:02	17:09	17:13	0:13	48.091939, 20.770392	1
36.	17:05	17:09	17:16	17:20	0:15	48.104935, 20.740534	1
37.	17:23	17:23	17:30	17:34	0:11	48.101846, 20.710331	1
38.	17:24	17:30	17:33	17:37	0:13	48.081587, 20.769546	1
39.	17:25	17:33	17:37	17:41	0:16	48.108009, 20.790945	1
40.	17:30	17:37	17:44	17:48	0:18	48.056097, 20.756928	1
41.	17:44	17:44	17:51	17:55	0:11	48.072831, 20.770451	1
42.	17:55	17:55	18:05	18:09	0:14	48.094831, 20.769954	3
43.	17:55	18:05	18:12	18:16	0:21	48.097037, 20.707767	2
44.	18:02	18:12	18:19	18:23	0:21	48.119362, 20.786367	2
45.	18:10	18:19	18:26	18:30	0:20	48.082859, 20.776438	2
46.	18:17	18:26	18:33	18:37	0:20	48.090858, 20.803443	1
47.	19:01	19:01	19:08	19:12	0:11	48.073979, 20.782634	1
48.	19:04	19:08	19:15	19:19	0:15	48.103352, 20.726441	1
49.	19:30	19:30	19:37	19:41	0:11	48.100536, 20.789361	1
50.	19:33	19:37	19:44	19:48	0:15	48.101906, 20.782653	1
51.	20:00	20:00	20:07	20:11	0:11	48.086240, 20.787318	1
52.	20:02	20:07	20:14	20:18	0:16	48.101168, 20.805454	1
53.	20:05	20:14	20:21	20:25	0:20	48.102236, 20.718332	2
54.	20:08	20:21	20:28	20:32	0:24	48.102426, 20.780732	2
55.	20:12	20:28	20:31	20:35	0:23	48.079875, 20.770089	1
56.	20:15	20:31	20:38	20:42	0:27	48.102836, 20.779172	1
57.	20:22	20:38	20:45	20:49	0:27	48.101442, 20.792967	2
58.	20:25	20:45	20:52	20:56	0:31	48.089784, 20.725582	2
59.	20:33	20:52	20:59	21:03	0:30	48.068804, 20.827343	2
60.	20:50	20:59	21:03	21:07	0:17	48.101660, 20.789066	2



Széchenyi István út 54, Miskolc, 3530
Arany János tér 1, Miskolc, 3526
Baross Gábor út 13, Miskolc, 3527
Korach Mór u. 23, Miskolc, 3529

Útvonalterv elküldése ide: samsung SM-A520F

Corvin u. érintésével 1 óra
1 óra forgalom nélkül 29,3 km
Részletek

***Figure 1.** Optimal route plan for Group 1. visualized on a diagram and map*

3. COST ANALYSIS OF THE CASE STUDY

Using the previously described methods, we analysed additional micromobility and car-based groups and found a strong correlation between the number of addresses and the performance capacity of the vehicles. From this information, we can easily determine the number of vehicles and couriers required to complete the deliveries, as well as the duration of the transport routes.

For electric scooters, a courier can handle a maximum of 2 (Bishkek) – 3 (Miskolc) addresses per group. This makes them efficient in smaller zones, but at least 3 (Miskolc) – 4 (Bishkek) couriers are required to ensure an adequate service level. Bicycle couriers can realistically serve 4 (Bishkek) – 5 (Miskolc) addresses per courier, but 3 couriers are still necessary for smooth urban deliveries.

Car couriers can reliably manage 5 (Bishkek) – 6 (Miskolc) addresses, but to optimize efficiency, it is advisable to employ 3 couriers. E-mopeds, however, perform exceptionally well, capable of handling up to 5 (Bishkek) – 7 (Miskolc) addresses while transporting 8 pizzas simultaneously. Even with mopeds, at least 2 (Miskolc) – 3 (Bishkek) couriers are needed for continuous operation.

When designing the vehicle fleet, it is important to consider not only route planning and efficiency but also the costs associated with different vehicle types. These include maintenance fees, fuel costs, daily courier wages, and leasing fees, all of which play a key role in assembling an optimal fleet. We gather this information by consulting restaurants, drawing from our own experience, and referring to official price lists (for electricity and fuel). Our goal is to create a homogeneous fleet to simplify maintenance, courier training, and logistics processes. The range of micromobility vehicles – e-scooters, e-bikes, and e-mopeds – was determined to be 60 km per charge. Fuel-powered car costs were also calculated for 60 km to provide a unified basis for cost comparison.

The delivery costs were calculated as the sum of the following elements [17]:

- Maintenance fee (per km)
- Fuel cost (per km)
- Vehicle leasing fee (daily)
- Courier daily wage

Maintenance and vehicle leasing fees are estimated based on government data and official prices, rental/leasing rates from companies, and personal experience [18, 19]. The total maintenance fee is proportional to the kilometres driven and the number of vehicles. Fuel costs are determined solely by the distance travelled. Leasing fees are proportional to the number of vehicles, while courier wages depend on the number of employees and estimated wage levels. The costs of different vehicle types are detailed in Table IV, based on a daily breakdown for a 60 km distance.

Based on the analysis of the costs associated with different vehicle types, we found that in urban environments, gasoline cars are the most expensive in both cities, primarily due to high maintenance and fuel costs. In contrast, micromobility tools – such as scooters, bicycles, and mopeds – offer a more sustainable and cost-effective alternative, especially for shorter distances.

Table IV.

Transport cost of vehicle types in restaurant delivery

		E-scooter			E-bike			E-moped			Micro car (petrol)			Electric micro car		
		Unit price (EUR)	quan.	Total (EUR)	Unit price (EUR)	quan.	Total (EUR)	Unit price (EUR)	quan.	Total (EUR)	Unit price (EUR)	quan.	Total (EUR)	Unit price (EUR)	quan.	Total (EUR)
Miskolc	Maintenance fee (60 km)	1	10	10	2	7	14	2,5	5	12,5	4	5	20	2	5	10
	Fuel cost (60 km)	0,04	10	0,4	0,07	7	0,49	0,2	5	1	6,5	5	32,5	1	5	5
	Leasing fee (per day)	2	4	8	3	4	12	6	3	18	11	2	22	11	2	22
	Courier wage (per day)	30	3	90	30	3	90	35	2	70	35	2	70	35	2	70
	Summarized			108,4			116,49			101,5			144,5			107

		E-scooter			E-bike			E-moped			Micro car			Micro car		
		Unit price (EUR)	quan.	Total (EUR)	Unit price (EUR)	quan.	Total (EUR)	Unit price (EUR)	quan.	Total (EUR)	Unit price (EUR)	quan.	Total (EUR)	Unit price (EUR)	quan.	Total (EUR)
Bishkek	Karbantarási díj (60km)	0,7	14	9,8	1,6	8	12,8	1,5	6	9	2,5	6	15	1,3	6	7,8
	Üzemanyag díj (60 km)	0	14	0	0	8	0	0	6	0	4	6	24	0,1	6	0,6
	Lízing díj (nap)	2	6	12	4	4	16	5	4	20	10	3	30	10	3	30
	Futár díj (nap)	9	4	36	9	3	27	10	3	30	10	3	30	10	3	30
				57,8			55,8			59			99			68,4

When designing the fleet, it is important to consider that electric vehicles require a charging time of up to 4 hours, necessitating backup vehicles to ensure continuous service. As such, a fleet using e-scooters or e-bikes requires 4 vehicles in Miskolc, and 6 e-scooters and 4 bikes in Bishkek.

Table 4 summarizes the results, showing that combustion engine cars perform the worst, primarily due to high maintenance and leasing costs. Electric vehicles, particularly e-mopeds and e-bikes, show more favourable results, with total costs of approximately 100 EUR per day in Miskolc and around 55 EUR per day in Bishkek for 60 orders.

4. CONCLUSION

Our findings indicate that while electric vehicles require a higher initial investment, they are more economical and environmentally friendly in the long term. As detailed previously, the adoption of electric vehicles is not only cost-effective but also stands out in terms of sustainability. Their role in modern mobility solutions is increasingly significant due to their contribution to long-term cost reduction and environmental consciousness.

In the first part of the research, we provided a detailed overview of the concept and significance of micromobility in promoting sustainability in modern urban transportation. We introduced various micromobility devices—such as electric scooters, skateboards, bicycles, and mopeds—and highlighted their flexible application in urban traffic and environmentally friendly characteristics.

In the second part of the study, we analysed the importance of route planning and the central role of the "last mile" concept in the urban supply chain. We emphasized this aspect because our goal was to present a solution to a route planning problem arising in a modern urban environment from the perspective of a pizza courier, but this can be used in any restaurant delivery system. The problem-solving process of grouping and route planning was elaborated in detail, followed by a cost analysis for the selected vehicle types.

In the concluding section, we find that in Miskolc electric mopeds, and in Bishkek e-bikes can be the most efficient vehicles in an urban setting. These vehicles are economical in the long run, environmentally friendly, and offer fast and flexible usage in urban transportation with favourable maintenance costs.

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