Analysis of the Impact of Microcars on Carbon Emission and Traffic Congestion

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INTRODUCTION

Urban traffic systems today face mounting challenges in the form of congestion, limited infrastructure, and increasing carbon emissions. Microcars—small, energy-efficient vehicles—are emerging as a promising solution to these issues. Their compact size reduces road and parking space requirements, while electric variants emit significantly fewer greenhouse gases compared to traditional internal combustion engine (ICE) vehicles. This study investigates the potential of microcars to enhance urban mobility and environmental sustainability through large-scale traffic simulations of Berlin using the Multi-Agent Transport Simulation (MATSim).

METHOD

The research employs the Multi-Agent Transport Simulation (MATSim) framework, which models individual agents' behavior within a real-world network. The study uses the well-documented Berlin urban network as a case study, using an open-source network and population dataset created and calibrated by the Technische Universität Berlin (Ziemke et al., 2019). For this study, a 3% sample of the Berlin population was used to balance simulation accuracy and computational efficiency. Using Berlin City's urban transport system as a case study, 48 scenarios were simulated, varying in microcar replacement ratios (25%–100%), maximum speeds (50–120 km/h), and Passenger Car Equivalent (PCE) values (0.5–0.7). Performance indicators included mode share, average speed, travel duration, congestion index, and environmental metrics such as fuel consumption and CO_2 emissions. Agent-level decision-making and adaptive behavior were incorporated to reflect dynamic travel adjustments in response to the microcar introduction.

FINDINGS

Simulation results indicate that replacing conventional cars with microcars improves traffic and environmental conditions. Table 1 is an overview of best-performing and worst-performing scenarios across all metrics. The most substantial benefits were observed at 100% replacement with a high maximum speed (i.e., 90 or 120 km/h speed) and small configuration (i.e., 0.5 PCE) of microcars: average speed increased by 4.3%, travel duration dropped by 9.8%, and carbon emissions were reduced by 11.4%. PCE had a more pronounced impact than maximum speed, highlighting the spatial efficiency of microcars. Although higher replacement ratios consistently led to better traffic flow and emissions outcomes in general, introducing microcars with too low maximum speed and big in size led to worse traffic performance than the base scenario. Mode share for private vehicle usage also rose, suggesting a potential modal shift from public to private transport if microcars are adopted widely.

Table 1. Overview of best-performing and worst-performing scenarios across all metrics

	base	best scenario			worst scenario		
	value	value	change relative to the base scenario	variable combination*	value	change relative to the base scenario	variable combination*
avg. speed of car&microcar [km/h]	37.6	39.2	4.3%	[100%, 90km/h, 0.5]	37.4	-0.5%	[50%, 50km/h, 0.7]
mode share of car&microcar [%]	25.7	25.7	0.0%	base	28.1	9.4%	[100%, 50km/h, 0.5]
avg. duration of car&microcar [h/day,agent]	2.14	1.93	-9.8%	[100%, 120km/h, 0.5]	2.14	0.0%	base
congestion index	0.741	0.745	0.5%	[100%, 120km/h, 0.5]	0.737	-0.5%	[100%, 50km/h, 0.7]
					0.737	-0.5%	[75%, 50km/h, 0.7]
CO2 eq. [kt]	24.6	21.8	-11.4%	[100%, 120km/h, 0.7]	24.6	0.0%	base
fuel consumption [TJ]	292	255	-12.6%	[100%, 120km/h, 0.7]	292	0.0%	base

*The variable combination represents the values of microcar replacement ratio [%], microcar maximum speed [km/h], and microcar PCE in the scenario

CONCLUSION

This study examined the impact of introducing microcars into an urban transport network through a large-scale agent-based simulation using MATSim. The simulation results indicate that increasing the microcar replacement ratio leads to consistent improvements in traffic performance and environmental outcomes. Notably, average travel speed increases and travel duration decreases, particularly when microcars are smaller (lower PCE). While introducing microcars slightly increases the overall mode share of private vehicles, this shift does not significantly hinder traffic flow or negate the environmental benefits. On the contrary, both fuel consumption and carbon emissions decrease substantially with higher levels of microcar adoption, underscoring their potential as a low-emission urban mobility solution.

Several limitations must be acknowledged. Microcar adopters were identified based on simplified assumptions regarding travel distance and household size, which may not fully capture real-world adoption behavior. Geographical, psychological, and economic factors influencing adoption were beyond the scope of the simulation model.

Future research should aim to address these gaps by incorporating survey data or real-world pilot studies to improve the accuracy of microcar adoption modeling. Additionally, investigating the integration of microcars with shared mobility systems or autonomous vehicle technologies could provide further insights, especially concerning parking space management and network effects.

REFERENCE

Ziemke, Dominik; Kaddoura, Ihab; Nagel, Kai (2019): The MATSim Open Berlin Scenario: A multimodal agent-based transport simulation scenario based on synthetic demand modeling and open data. In Procedia Computer Science 151, pp. 870–877. DOI: 10.1016/j.procs.2019.04.120.