Title

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Authors

Mohiuddin, Hossain
Fitch-Polse, Dillon T., PhD

Publication Date

2024-09-01

DOI

10.7922/G2JW8C7Z

RESEARCH REPORT

Institute of Transportation Studies | UNIVERSITY OF CALIFORNIA

Is Micromobility Being Used in Place of Car Trips in Daily Travel (or "Trip Chains")?

Hossain Mohiuddin, Ph.D. Candidate, Institute of Transportation Studies, University of California, Davis
Dillon T. Fitch-Polse, Ph.D., Research Faculty, Institute of Transportation Studies, University of California, Davis

September 2024

ITS UCDAVIS Institute of Transportation Studies

Report No.: UC-ITS-2023-04 | DOI: 10.7922/G2JW8C7Z

Technical Report Documentation Page

1. Report No. UC-ITS-2023-04	**2. Government Accession No.** N/A	**3. Recipient's Catalog No.** N/A
4. Title and Subtitle Is Micromobility Being Used in Place of Car Trips in Daily Travel (or "Trip Chains")?		**5. Report Date** September 2024 **6. Performing Organization Code** ITS-Davis
7. Author(s) Hossain Mohiuddin [https://orcid.org/ 0000-0002-6842-2424] Dillon T. Fitch-Polse, PhD, https://orcid.org/0000-0003-3760-322X		**8. Performing Organization Report No.** UCD-ITS-RR-24-66
9. Performing Organization Name and Address Institute of Transportation Studies, Davis 1605 Tilia Street Davis, CA 95616		**10. Work Unit No.** N/A **11. Contract or Grant No.** UC-ITS-2023-04
12. Sponsoring Agency Name and Address The University of California Institute of Transportation Studies www.ucits.org		**13. Type of Report and Period Covered** Final Report (October 2022 – April 2024) **14. Sponsoring Agency Code** UC ITS
15. Supplementary Notes DOI:10.7922/G2JW8C7Z		

16. Abstract

To understand the extent to which micromobility services such as bike-share and scooter-share are enabling car-light lifestyles by replacing driving, we explore the trip-chaining patterns of micromobility users. We use travel diary data collected from micromobility users in 48 cities across the US. Our analysis incorporated 15,985 trip chains from 1,157 survey participants who provided at least seven days of travel diary data, and an imputed dataset of 35,623 trip chains from 1,838 participants from the same survey. Our analysis of both datasets shows that a considerable portion of car owners are leaving their cars at home when using micromobility. This suggests that, for a subset of users, micromobility can form part of a car-free or car-light day of travel, despite having a car available. Trip chains with less frequent car use are composed of a variety of different modes in combination with micromobility. Micromobility services are supportive of complex trip chains that include both work and non-work trips with reduced reliance on cars. The use of micromobility services tends to entirely replace shorter car trips on shorter-length trip chains. Our findings show the importance of considering the chain of trips rather than individual trips to understand the sustainability potential of micromobility services. The policy implications of these findings are improving methods of travel behavior analysis of shared mobility services.

17. Key Words Micromobility, shared mobility, trip chaining, mode choice, travel surveys		**18. Distribution Statement** No restrictions.	
19. Security Classification (of this report) Unclassified	**20. Security Classification (of this page)** Unclassified	**21. No. of Pages** 36	**22. Price** N/A

Form Dot F 1700.7 (8-72)   Reproduction of completed page authorized

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Acknowledgments

This study was made possible with funding received by the University of California Institute of Transportation Studies from the State of California through the Road Repair and Accountability Act of 2017 (Senate Bill 1) and/or a one-time General Fund allocation in the 2021 State Budget Act for the Resilient and Innovative Mobility Initiative. The authors would like to thank the State of California for its support of university-based research, and especially for the funding received for this project.

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Executive Summary

Executive Summary

Micromobility services are an important part of the new shared mobility revolution. After the introduction of micromobility services such as electric bike-share and scooter-share, some cities have seen mode shifts from cars to bike-share and scooter-share while other cities have predominately seen shifts from transit to bike-share. The effect of micromobility may transcend mode substitution and transit connections by influencing daily travel patterns and mode choices beyond individual trips. For example, it is possible that micromobility can influence strings of multiple trips in a row starting and stopping at home, or “trip-chain,” behavior. This may have far-reaching impacts, contributing to the attainment of sustainability goals. Previous research suggests that trip-chaining patterns have been getting more complex in recent years with more stops per chain, and the car has been observed to be the most convenient mode to accommodate these complex chains. In this report, we examine evidence on micromobility services and evaluate whether they enable people to perform complex trip chains, both for commuting and non-commuting trip purposes, without being entirely dependent on cars.

To understand the extent to which bike-share and scooter-share micromobility services are replacing driving and enabling complex trip chaining, we explore the trip-chaining patterns from a travel diary of micromobility users collected from 48 cities in the US. Data are from the American Micromobility Study (Fitch-Polse et al., 2023), which included a 21-day smartphone-based travel diary recorded by micromobility users using a third-party Resource System Group (RSG) app in the summer of 2022. Invited participants were required to install a smartphone app (*rMove*) that tracked their trips and asked trip-related questions. The travel diary survey collected detailed information about the daily travel of respondents. After completing each trip, individuals were asked in the travel diary survey through the *rMove* app about their trip purpose and their use of modes during their trip. Approximately 50% of participants did not provide mode information for each trip that is required to produce complete profiles of their trip chains. Some of the participants had missing trip information for some trips and other participants had missing trip information for the entire travel day. To manage the missing data and missing trip labels, we employed data imputation and data sub-setting approaches. First, we subset data such that each participant had at least a seven-day travel diary and did not have any missing data or labels for those days. Using this approach, we extracted 15,985 trip chains from 1,157 individuals. For missing values, we use imputed data that contains missing modes, trip purposes, and other travel-related information. Using this approach, we extracted 35,623 trip chains from 1,838 individuals.

We conducted a two-part trip chain analysis, one on car and micromobility use within trip chains, and the other on trip chain complexity and micromobility use. Within the car use analysis, we considered two mobility choice patterns: (1) starting a trip chain without a car and (2) starting a trip chain with a car. The effects of micromobility on car replacement can be explained by two effects: direct and indirect. The direct effect is when micromobility replaces car trips and the indirect effect is when the use of micromobility influences individuals to replace car trips with other modes. In general, car users start trip chains with their cars. We use this initial mode factor to differentiate between instances of micromobility directly replacing cars at the trip level and indirectly replacing cars at the chain level. Within the trip chain complexity analysis, we focused on the activity configuration within the chain. Individuals' trip chains can be *simple* with either primary (work-based) or secondary activities (non-work-based) in a chain or *complex* with a mixture of both primary and secondary activities in a chain. We consider the availability of personal vehicles and micromobility access when evaluating car use within trip chains and trip-chain complexity.

Results of these two analyses indicate that access to, and use of, micromobility services enable individuals to rely less on personal cars in their travel. Our first analysis shows that:

- The presence of micromobility services in chains that start with a personal car corresponds with much lower car use compared to chains that do not incorporate micromobility. This suggests both direct and indirect effects of micromobility use on replacing car trips within a chain.
- The use of micromobility may enable individuals to perform longer chains with more activities in a more multimodal way in combination with a personal car.
- Approximately 79% of car-owning individuals leave their car at home at the beginning of the travel day in part due to their planned use of micromobility services to form a car-free day of travel.
- Regarding trip chaining complexity, in most cases, complex chains that start with a car trip tend to be much longer in length with the presence of micromobility services, suggesting micromobility may be enabling longer complex chains without being fully reliant on cars. In other cases, complex chains that do not start with a car and have micromobility are much shorter in length and consist of shorter-length trips. In the absence of micromobility services from the transportation landscape, we would have likely seen a higher portion of car trips for such shorter complex chains.
- Both car owners and non-car owners who use micromobility perform complex chains with multiple work and non-work activities at a similar rate.

Overall, our findings indicate that micromobility services are likely enabling some individuals to perform complex chains without being reliant on cars, which supports our initial hypothesis that micromobility can assist in accommodating complex chains. Our findings have several policy implications. They show the importance of considering the chain of trips rather than individual trips to understand the sustainability potential of micromobility services (Figure ES-1).

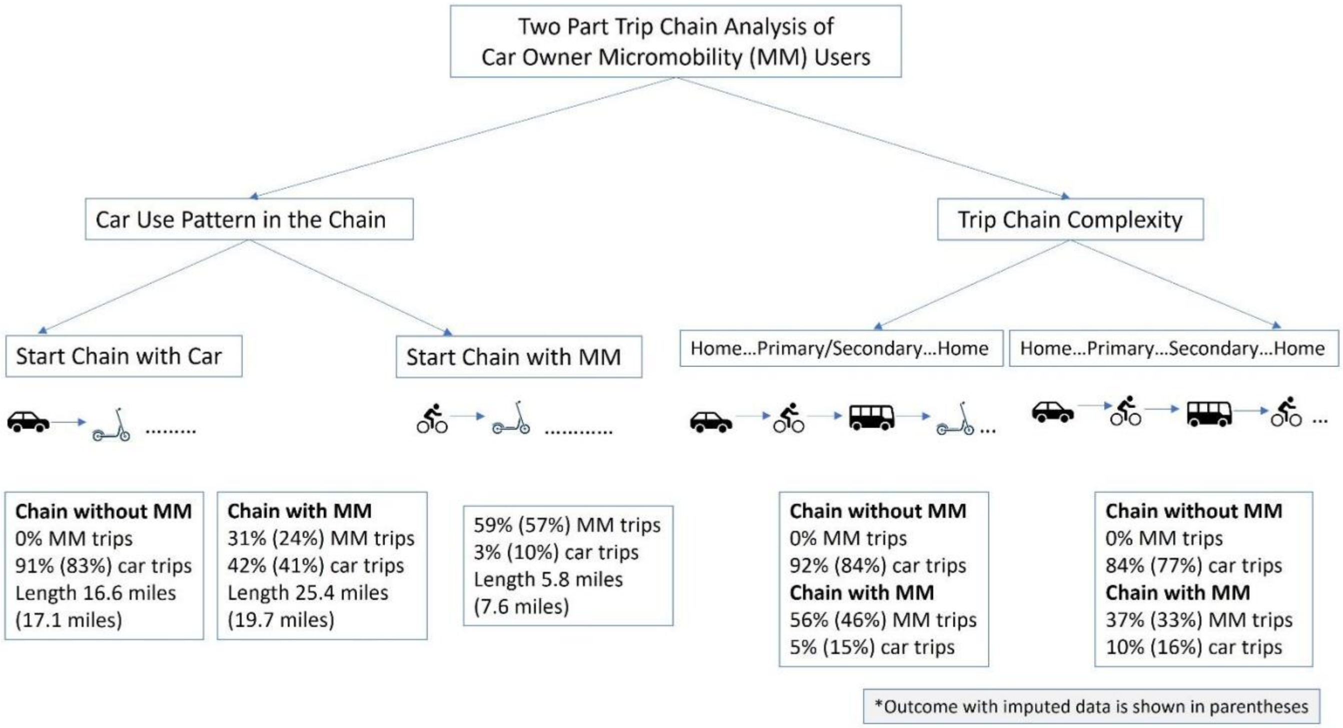

Figure ES-1. Findings of the trip chain analysis.

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Introduction

Micromobility systems, including electric bike-share and scooter-share, are an important part of the new shared mobility revolution. Between 2017 and 2023, massive growth in shared micromobility trips has been observed, especially in scooter trips. In 2019 alone, micromobility accounted for an estimated 136 million trips in the United States (US) (National Association of City Transportation Officials, 2020). Although ridership declined in the COVID period, the services bounced back in 2021 with 112 million trips (NACTO 2022), 130 million trips in 2022 (NACTO 2023), and 157 million trips in 2023 (NACTO 2024). After the introduction of micromobility services, mode shifts from cars to bike-share and scooter-share were observed in some cities while shifts from transit to bike-share were observed in others (Fishman et al., 2013). Rather than competing with transit, micromobility systems may support transit by serving as a “first-mile and last-mile” mode (Liu and Miller, 2022; Mohiuddin, 2021; Shaheen and Chan, 2016). However, it is uncertain whether micromobility can live up to its potential as an environmentally sustainable mobility option by replacing driving and facilitating public transit.

The availability of micromobility services may influence people’s daily travel patterns and mode choices. People’s travel patterns can be defined in several ways: (1) as the combination of trip chaining, or linking of trips that start from home and then stop at home when an individual returns home, (2) as trip-making patterns within a chain (types of trips), and (3) as mode use patterns for those trips. Generally, a trip chain begins when an individual leaves home and ends when they return home (Primerano et al., 2008). When individuals travel at night, trip chains can span days. Based on this definition, an individual may have multiple trip chains in a day, each reflecting certain types of activity patterns. Some research suggests that trip-chaining patterns have been getting more complex in recent years and that the mean number of stops in a trip chain is increasing (Mcguckin and Nakamoto, 2004). Previous research suggests that complex trip chains require flexible travel modes, and that people prefer cars to other modes for these trips (Hensher and Reyes, 2000; Huang et al., 2021). For non-commuting tours, transit may be more effective in providing flexibility to conduct complex trip chains due to the proximity of transit service density to high-activity locations (Currie and Delbosc, 2011). In this study, we examine the extent to which micromobility services enable (1) general car-free trip chaining and (2) car-free complex trip chaining, both for commuting and non-commuting trip purposes.

Methods

Data Collection

We used smartphone travel diary data collected from the American Micromobility Study in 48 cities across the US (Fitch-Polse et al., 2023) (Figure 1). Initially, study cities were mainly selected based on a balance of biking environment (i.e., bike score), walk score, transit score, percentage of transit commuters, type of transit services, percentage of bicycle commuters, city size, and population density. The selection was also based on the presence and size of the market of the following micromobility operators who recruited participants: *Bird*, *Lime*, *Lyft*, *Spin*, and *Superpedestrian*. Recruitment included a trip-weighted protocol, increasing the likelihood of recruiting participants who used micromobility services frequently. This means that the sample used in this report is biased toward frequent micromobility users. This limits the generalizability of our results. Future analyses will include trip weights to reduce this bias. Other biases, such as the balance between users in each city, also exist. See Fitch-Polse et al. (2023) for full details about participant recruitment.

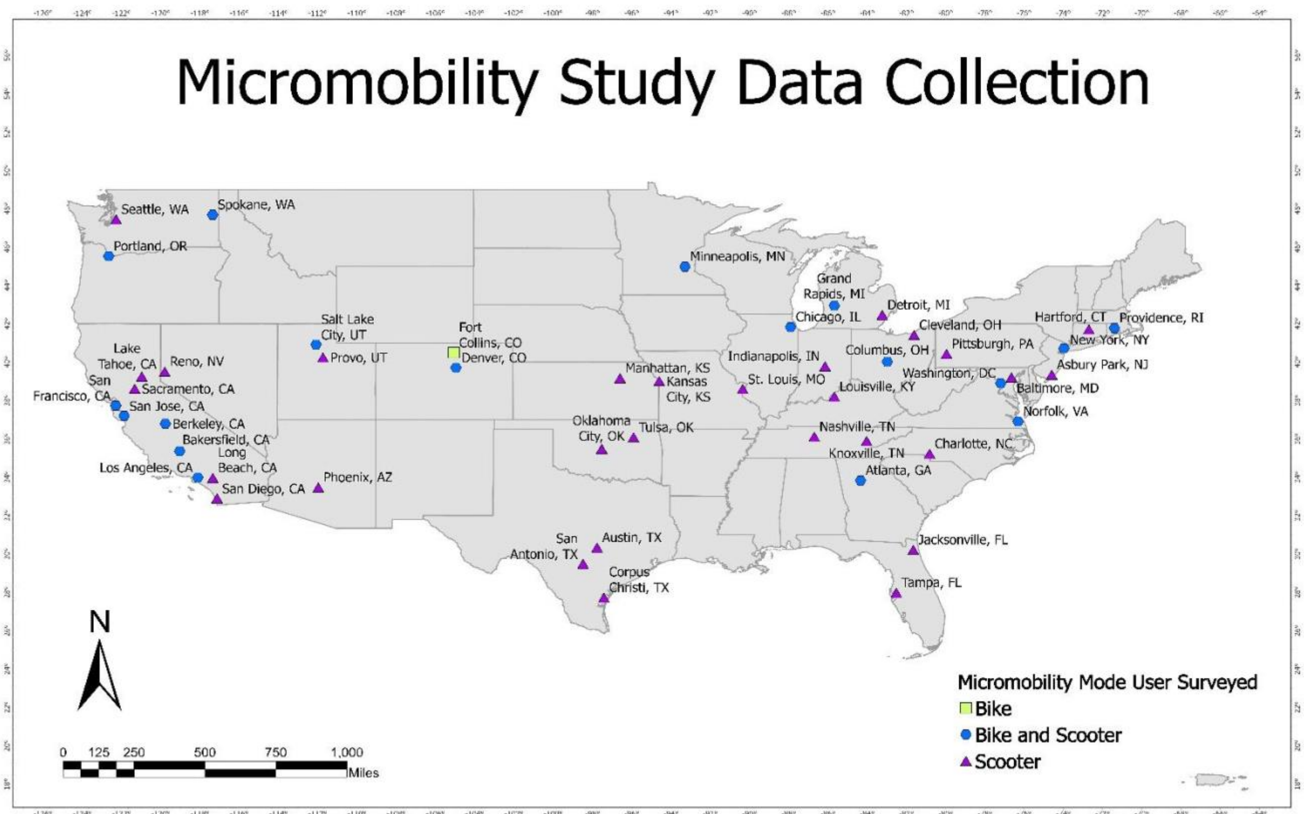

Figure 1. Study area with micromobility users surveyed by micromobility type. Smartphone travel diary data were collected from micromobility users in 48 US cities (Source: Produced by Authors with shape files from Census.gov) (Data can be requested from the authors).

Travel Diary Survey

We conducted a 21-day data collection effort. Micromobility users kept smartphone-based travel diaries with a third-party software application or “app” in the summer of 2022 (RSG, 2022; Fitch-Polse et al., 2023). Invited participants were required to install the smartphone app *rMove* that tracked their trips and asked trip-related questions. A total of 2,206 participants downloaded the app. The travel diary collected detailed information of trips such as origin, destination, trip time, duration, purpose, mode used on the trip, etc. After completing each trip, the *rMove* app prompted individuals for information about their trip purpose(s) and their travel mode(s) during their trip. If the mode was transit, they were asked about the first and last-mile connection mode for the transit trip. If the mode was micromobility, they were asked about what type of micromobility service they were using, what mode they were replacing while using micromobility, and where they parked the micromobility device. In addition to trip-related information, the *rMove* app also collected socio-demographic information from survey participants.

Trip Chain Analysis Methodology

Defining Trip Chains

There are several definitions of trip chains (Primerano et al., 2008; Schneider et al., 2021). We define a trip chain as starting when an individual leaves home and ending when they return home on the same day (Primerano et al., 2008; Schneider et al., 2021). We built individual trip chains by applying a home-to-home-based tour approach with travel diary data. In this schema, trip-making begins from home and ends when the traveler returns home on the same day. With this approach, a person can have multiple trip chains in a day. This gives an impression of the individuals’ travel patterns for an entire day. Entire-day travel requires an individual to make preliminary decisions about how they will travel during the day. Studies show that trip chain decisions precede mode choice (Li et al., 2013; Yang et al., 2016; Ye et al., 2007). For this reason, when defining a chain, it is important to consider all activities throughout an entire day rather than focusing only on traveling between activities (Primerano et al., 2008). Home-to-home trip chains often include activities such as going to work, getting meals, recreation, and shuttling children (Figure 2). In this analysis, we considered a journey to be a “trip” if it had a purpose. For example, we did not consider single or multiple changes of modes for a specific journey purpose as a trip but rather as the leg(s) of a multimodal trip.

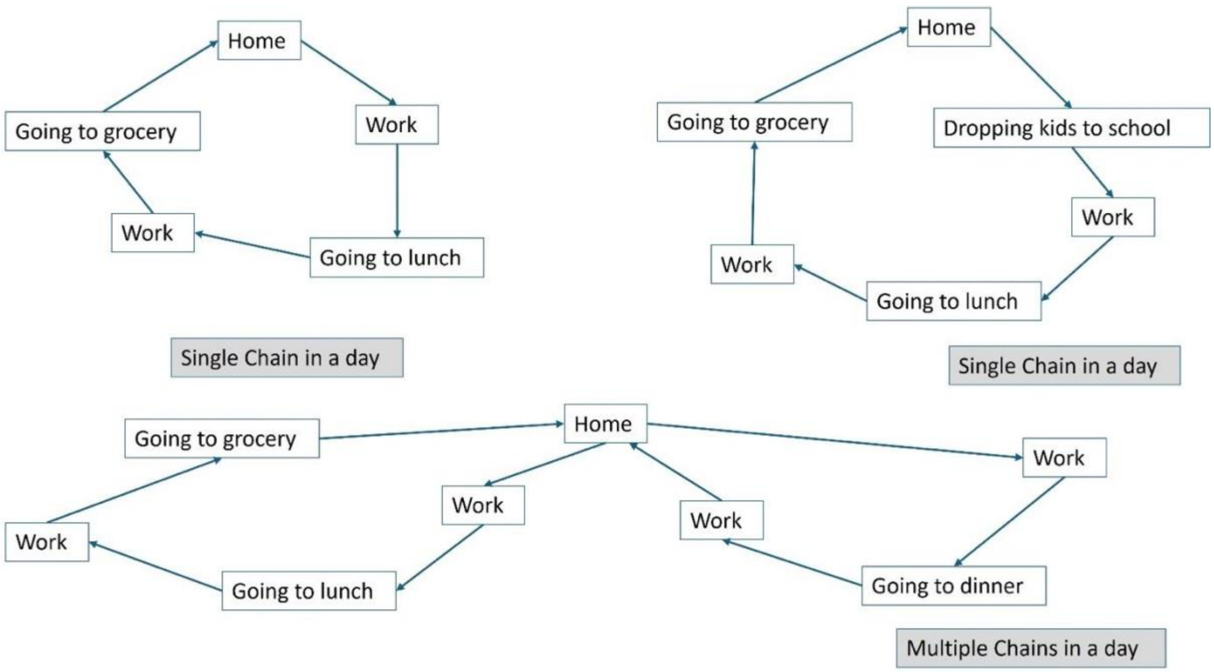

Figure 2. Trip chain examples based on a home-to-home approach.

Approximately 50% of the survey participants did not provide 21-day travel data, resulting in incomplete travel diaries. Likewise, approximately 50% of the participants did not provide mode information for each trip, making it impossible to produce trip chain profiles. In some cases, trip starts and ends did not happen at home on the same day as a portion ended their days at their friend's home, hotels, etc. Those trips did not comply with the definition of a trip chain, so we dropped those trips from the analysis. Working with trip chaining data requires all travel data for an individual over several consecutive days. Collecting such data is time-consuming and costly. Datasets containing multi-week information are needed to accurately discern mode choice patterns for weekdays and weekends as well as any mode choice pattern(s) associated with days of the week (Schlich and Axhausen, 2003; Vij et al., 2013). To manage missing data and missing trip labels, we took two approaches: data imputation and data sub-setting. First, we subset the data such that each participant had at least a seven-day travel diary and did not have any missing data or labels for those days. After sub-setting, we extracted 15,985 trip chains from 1,157 individuals (Table 1). American Micromobility Study research team imputed modes, trip purposes, and other travel-related information for missing values of the trip data collected from the travel diary survey. Using that imputed dataset, in this study, we extracted 35,623 trip chains from 1,838 individuals.

There are some differences between the subset data (participant-provided mode) and the imputed data (participant-provided and model-estimated mode for the missing data) in terms of mode representation for a trip. With the subset dataset, we used the reported mode of the survey participants. The imputed dataset did not differentiate between modes such as a personal household vehicle, car-share, ridehail, taxi, etc., and considered all these modes into a single "car" mode category. The subset dataset does differentiate modes as reported by participants. The imputed dataset did not differentiate between micromobility service types. Bike-share, scooter-share, personal micromobility devices, and other micromobility types were merged into a single category of "micromobility." In the imputed dataset, multimodal trips reported by participants were broken down into single trip legs with distance, mode, and other trip-related information for those trip legs.

Differences in the two datasets may yield differences in results regarding the use of cars in trip chains as well as the number of stops within a chain. Overall, the imputed dataset provides an opportunity to examine a larger dataset about more general travel, and the subset dataset provides an opportunity to examine a smaller but more detailed look at the trip-chaining behavior of micromobility users.

Table 1. Individual characteristics of participants in the travel diary survey and trip chain characteristics.

Characteristics of Travel Diary survey participants			
Variable		**Subset Data (n =1,157)**	**Imputed Data (n=1,838)**
Race	White	64%	69%
	Black	7%	13%
	Asian	12%	12%
	Other	17%	6%
Gender	Woman	37%	36%
Employment Status	Employed	88%	78%
Household Income* (*approximately 4% did not report their income*)	Less than $50,000	28%	32%
	Between $50,000 to $150,000	45%	42%
	$150,000 or more	22%	22%
Driving license	Yes	77%	78%
Car ownership	Yes	55%	57%
Student status	Yes	17%	16%
Having children	Yes	11%	13%
Age	Less than 35	56%	58%
	35 to 55	36%	26%
	55 or more	8%	17%
Characteristics of trip chains			
Number of chains		15,985	35,623

Characteristics of Travel Diary survey participants		
Variable	Subset Data (n =1,157)	Imputed Data (n=1,838)
Number of trips	45,386	1,28,568
Number of individuals	1,157*	1,838
Number of travel purposes in a chain (mean)	2.84	3.61
Number of modes in a chain (mean) **	3.69	4.92
Length of a chain (in miles) (mean)***	9.07	10.18
% of chains by car owners	59%	57%
Micromobility use per chain (mean)	12%	14%
Public transit use per chain (mean)	5%	3%
Car use per chain (mean)	26%	36%****
Walk per chain (mean)	44%	48%
Transportation Network Company (TNC) use per chain (mean)	2%	- *****

Note: *Number of individuals used in the final trip chain analyses as some of the original survey participants did not provide all the trip information for at least seven days that have both weekday and weekend information

**A portion of the trip has multiple modes thus the value is higher than the number of stops/ travel purposes

***As the trip distance calculation was uncertain, we removed trip chains more than 100 miles in this calculation

***Car trip includes personal car, ridehail, taxi, and car-share services

****Imputed data do not include TNC/ ridehail as those are included in the combined imputed car category

Trip Chaining Analysis

We conducted a two-part trip chain analysis. The first part focuses on general car and micromobility use within trip chains and the second part focuses on car and micromobility use within complex trip chains. The following section describes how each analysis is used to answer the overarching research question: *to what extent is micromobility enabling car-light lifestyles by replacing driving?*

Car and Micromobility Use Patterns in the Trip Chain

We analyze micromobility use patterns in trip chains for both car owners and non-car owners. We focused our discussion in this section on car owners and their use of micromobility services in conjunction with cars. To analyze the trip chain data of car owners, we considered two patterns based on car use: one in which individuals start a trip chain without a car, and another in which individuals start a trip chain with a car. In general, car users start their trip chains with their cars.

In the first pattern, we focus on individuals who start their trip chain without their car. This may indicate that they are leaving their cars at home, or they may have parked their cars in a location that is not home (the latter was rare). A car owner may start their chain without a car due to the unavailability of a car. They may also start their chain without a car due to the availability/access of micromobility services from nearby locations. It is difficult to determine whether an individual left their car at home due to the availability of micromobility. To capture that, after the travel diary survey, we conducted another survey where approximately one-third of the travel diary participants provided their detailed attitudes, perceptions, and other travel-related information during the travel diary period.

In the post-diary survey, we asked individuals how frequently they left their car at home for the day due to their planned use of micromobility during the travel diary period. We collected their responses in four ordinal categories: “Never,” “1-2 days,” “3-6 days,” and “7+ days.” We used these data to cross-validate our approach to understand the influence of micromobility services on individuals leaving their car at home at the beginning of their travel day. As only one-third of the travel diary participants completed the post-diary survey, we examined trip chains made by those participants with reference to their reported days of leaving their car at home due to micromobility services. As we collected data on an ordinal scale in the post-diary survey, we do not know the exact number of days they left their car. To account for this, we used two approaches: taking the mean of the reported interval of days and taking the upper limit of the reported days. For example, for the “7+ days” category, we took 7 for the mean approach and 14 for the upper limit approach. After that, we calculated the sum of a car owner starting their chain with micromobility service using the trip chain data of that individual. We then subtracted this sum from the calculated mean from the two previously described approaches.

In both approaches, we found for more than two-thirds of individuals, their reported days of leaving their car due to micromobility in the post-diary survey is higher than the number of times they start a chain with micromobility during the travel diary period. This validates our approach because, for most participants, we accurately captured the travel behavior of leaving their car at home due to planned micromobility use.

The pattern of planned micromobility use at the beginning of the trip chain by car owners relates to the sustainability potential of micromobility services. This pattern shows the complete or near-complete absence of cars from a chain of trips due to the availability of micromobility service. Not starting trips with a car leads to not using a car throughout the entire chain and, instead, using micromobility and other modes of transportation.

Previous trip-level analyses have only captured micromobility replacing one car trip during a trip, potentially understating the effect of micromobility on car replacement throughout the entire chain that consists of multiple trips. The effects of micromobility on car replacement can be explained by two effects: direct and indirect. The direct effect is when micromobility replaces car trips and the indirect effect is when the use of micromobility influences individuals to replace car trips with other modes. The trip-level replacement of cars can be understood as the direct effect of micromobility options replacing car use. However, trip chain level reduction in car use due to leaving the car at home at the beginning of a chain can represent the direct and indirect effect of micromobility in replacing car use. With some limitations, the trip-chaining analysis captures both the direct and indirect effects of micromobility.

In the second pattern, the car owner starts the chain with a car. We hypothesize that, due to the availability of flexible micromobility services in the middle of the trip chain, micromobility may still reduce car use during the trip chain when activities away from home are more conveniently accessed with micromobility. For example, this could be done by parking the car at work, using micromobility services in combination with other modes to perform various trips during the day, and then returning to the car to travel home. This pattern illustrates partial car avoidance from a chain as compared to the previous pattern of complete and/or near-complete avoidance. This pattern also shows both direct and indirect effects of micromobility services as described in the previous paragraph. To understand this pattern, we examine (1) chains that start with a car and have micromobility in the chain and (2) chains that start with a car and do not have micromobility use. We then compare car use between these types of chains to understand how the presence of micromobility influences the car use rate in trip chains.

Car and Micromobility Use on Complex Chains

To understand the contribution of micromobility for performing complex chains, we classified trip chains based on how individuals performed activities in a chain. We define two types of activities as primary: work/work-related and school/school-related and secondary: all other types of activities (e.g., shopping or errands, going for a meal, social/recreation, etc.). We consider a chain to be "complex" when an individual has both primary and secondary activities within the chain. There are nine categories of trip chain complexity types based on primary and secondary activities and the configuration of activities within the chain (Table 2). To summarize, a chain is "simple" if it has either a primary or secondary activity and a chain is "complex" when it has both primary and secondary activities.

We focus on trip chains made by car owners and non-owners separately because non-car owners have no personal car trips to replace, and we want to examine how micromobility assists them in performing complex chains. Car owners performed approximately 60% of the chains in the subset dataset and 57% of the chains in the imputed dataset. For simplicity, we focus on chains where the chain either starts with cars or micromobility or the chain includes micromobility at any point along the chain.

Table 2. Typology of trip chains based on activities within the chain (h=Home, p= Primary Activity, and s=Secondary Activity).

Chain Typology based on activities	Share of the chain (subset *n* = 15,895)	Share of the chain (imputed *n* = 35,623)	Description
h-p-h	12%	5%	A chain with only a primary (p) activity or activities (i.e., work or school) and no secondary (s) activity (i.e., any activity other than work or school). There can be multiple "p" in-between two home (h) anchors.

Chain Typology based on activities	Share of the chain (subset *n* = 15,895)	Share of the chain (imputed *n* = 35,623)	Description
h-s-h	76%	80%	A chain with only a secondary activity. There can be multiple "s" between "h."
h-p-s-h	5%	3%	When a chain starts with "p" and, before coming back home, ends with "s". There can be more than one "p" and "s" in this chain, however, a primary activity cannot come after a secondary activity. Individuals have to complete all their primary activities to start secondary activities before returning home.
h-p-s-p-s-h	1%	1%	Same as previous except there can be multiple "p" and "s" in the chain and a pattern like "s-s" in between two "p" indicating that an individual has multiple secondary activities between two primary activities and/or at the end indicating that an individual has multiple secondary activities before coming back to home after their primary activity.
h-p-s-p-h	2%	1%	When a chain starts with "p," is followed by "s," and, before coming back home, ends with "p." There cannot be more than one "s" in the chain.
h-p-s-p-s-p-h	0.5%	0.5%	Same as the previous, except there can be multiple "s" and also a pattern like "s-s" in between two "p" indicating an individual has multiple secondary activities between two primary activities.
h-s-p-h	1.5%	1.5%	When a chain starts with a secondary activity and ends with a primary. There can be multiple primary and secondary activities, however, the primary activity cannot be between secondary activities and secondary activities cannot be between primary activities.
h-s-p-s-p-h	0.3%	0.5%	Same as previous, however, there can be a primary activity between secondary activities and secondary activities between primary activities.
h-s-p-s-h	1%	2%	When a chain starts and ends with a secondary activity and has a primary activity between. There can be multiple primary activities in between "s," such as "p-p."
Other	-	4%	Other types of chains.

Limitations

Our results represent a wide variety of participants who use micromobility in different ways. Our sample size is large and the dataset features entries from numerous locations. This enables us to form hypotheses about the extent to which micromobility impacts people's travel beyond the trip level. By comparing our analysis with subset and imputed data, we offer additional insights into the role of micromobility in trip-chaining. However, our sampling method may not have produced a representative dataset. Without a population census about, or summary statistics for, micromobility users, it is difficult for us to generalize our results to suggest trends among the overall population of micromobility users in US cities. Nonetheless, our analysis yields insights about how micromobility options influence the travel patterns of study participants.

Another limitation of these data is the difficulty of assigning the causal influence of micromobility services on car use. Inferring the effect of micromobility on broader-level trip-chaining behavior requires many assumptions that may be faulty. In our results, we point out these assumptions, describe how we validate some of these assumptions, and discuss their potential implications on our findings.

Results and Discussions

Car and Micromobility Use Patterns in the Trip Chain

Trip-level mode replacement by micromobility services was greatest for walking at nearly 40% followed by transit at nearly 30% (Figure 3). Micromobility services also induce approximately 13% trips which would likely not happen in the absence of the service. Trip-level mode substitution data indicate that approximately 10% of micromobility trips replace car trips in this sample. However, this does not fully illustrate the sustainability potential of the service because it only represents the direct effect of the service on reducing car trips. We analyze trip chains of individuals to describe the indirect effects of micromobility services in the final sections of this report.

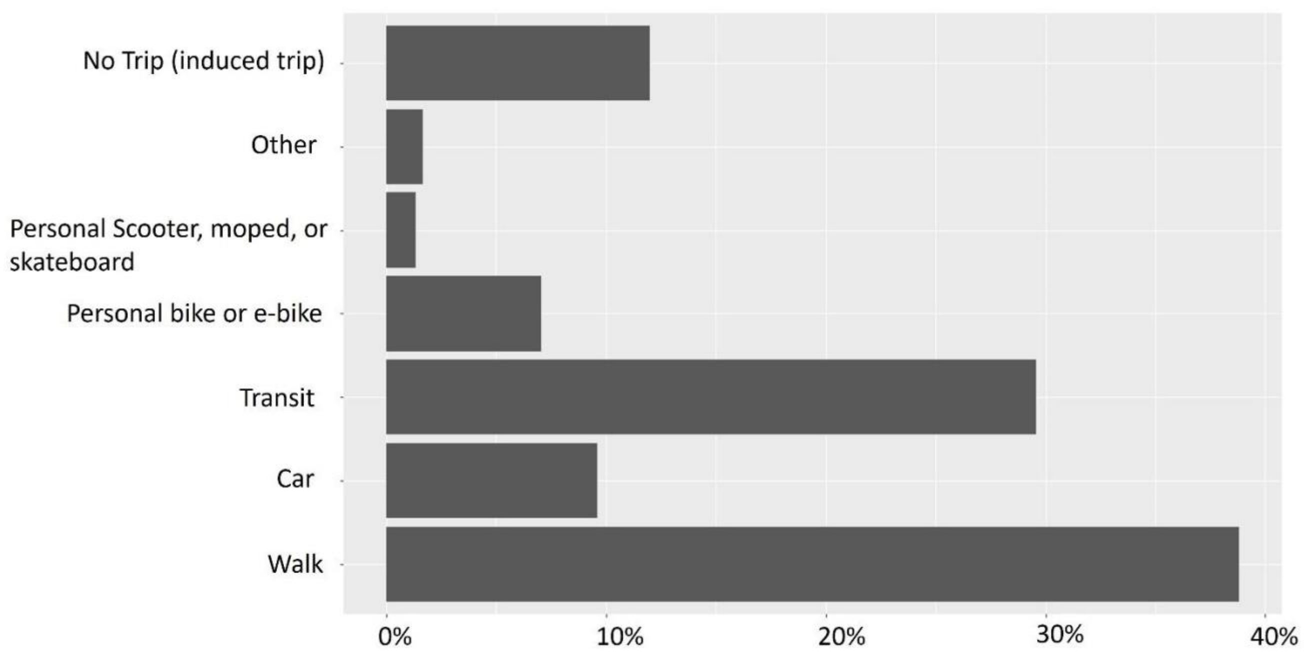

Figure 3. Trip-level mode replacement by micromobility services from the self-reported data.

Unlike Table 2 which focuses on the activity configuration, in this portion of the analysis, we developed trip chain typologies based on the pattern of car use within the chain. We developed eight types (Table 3) for subset data and ten types (Table 4) for imputed data. Results show that when an individual starts their travel from home with a car, and the chain does not have any micromobility trips, the entire chain consists mostly of car trips (Type 3 in tables 3 and 4). Between 83 (for imputed data) and 91% (for subset data) of trips within this trip chain type were made by car. The share of this chain type (Type 3) is also very common at a quarter (for subset data) to a third (for imputed data) of chains in this dataset. This suggests that, even though our data collection efforts focused on micromobility users, most of the participants rely on cars on trip chains.

The presence of micromobility services on chains that start with a personal car (Type 6) relates to much lower car use (41 to 42%) but is an option in only 1 to 2% of chains (tables 3 and 4). This suggests that, even if micromobility is the cause of car use reduction within a chain that starts with a car, the rarity of this type of chain means it may not reduce car use by much, overall. In contrast, Type 6 chains are small in proportion yet tend to be much longer in length (i.e., 25.4 miles on average) compared to any other chain. This suggests that, even if very rare, they may be an important pathway for micromobility to reduce car use. Chains that have micromobility trip components tend to have multiple activities involved (i.e., more stops) than chains that do not have micromobility trips. This indicates that the use of micromobility may enable individuals to perform longer trip chains with more activities in combination with a personal car.

The difference between mean car trips with and without the presence of a micromobility chain (Type 3 vs. Type 6) is greater than the mean frequency of micromobility trips in the chain (Type 6). This is because a large portion of car trips are replaced by modes other than micromobility services. This may be due to the direct and indirect effects of micromobility services in replacing car trips in trip chains, however, the contribution of micromobility is unknown, as we do not have any validation instruments.

When car owners do not start their trips with a personal car and, instead, use micromobility services during a trip chain (Type 4), they tend to use other modes (e.g., transit) at a very high rate compared to patterns without micromobility (Type 1). The rate of micromobility use in a chain becomes much higher when a similar type of individual starts the chain with micromobility services (Type 7). In both cases, the use of cars in the chain is minimal, yet the share of trip chains with these patterns is only 7 to 8%. However, we consider all trip chains performed by an individual during the diary period, not only the 32% of chains that feature micromobility. Micromobility services are not ubiquitous, thus, 7% to 8% of all the chains are a consequential segment. In these cases, a large portion of such chains likely happen when individuals leave their car at home due to their planned use of micromobility at the beginning of the chain. This was validated through post-diary surveys, as described in the methods section.

Leaving a car at home removes the car from the entire chain although an individual may use other modes apart from micromobility services, as shown in tables 3 and 4. These tables illustrate both the direct and indirect effects of micromobility services in forming a car-free or car-light day of travel for a portion of car-owning micromobility users. Approximately 79% of car-owning individuals reported leaving their car at home due to the planned use of micromobility during the travel diary period in the post-diary survey. This indicates that this pattern of car-free/car-light travel might be common among micromobility users in this sample.

Table 3. Results of car use pattern-based trip chaining with subset data (mm = micromobility). The number of chains analyzed (*n*) is 15,985.

Chain typology based on mode use	Start with mm	Has mm	Start with car	Non-car owner	Mean walk* (%)	Mean mm* (%)	Mean car* (%)	Mean transit mm* (%)	Mean number of stops	Mean Distance (miles)	Share of the chain (%)
1	no	no	no	no	71%	0%	4%	4%	2.6	5.7	24%
2	no	no	no	yes	70%	0%	0%	10%	2.6	5.8	27%
3	no	no	yes	no	6%	0%	91%	0%	3.2	16.7	27%
4	no	yes	no	no	32%	25%	2%	50%	3.5	13.6	1%
5	no	yes	no	yes	29%	27%	0%	55%	3.5	12.2	2%
6	no	yes	yes	no	18%	31%	42%	37%	4.2	25.4	1%
7	yes	yes	no	no	32%	59%	3%	62%	2.9	5.8	6%
8	yes	yes	no	yes	30%	61%	0%	66%	2.9	6.0	12%

Note: *Values in these columns are the percentages of a mode presence on a given type of chain (column A). For example, a value of 71% indicates that 71% of trips within a type of trip chain were made by that mode and the remaining 29% of trips used a different mode.

Table 4. Results of car use pattern-based trip chaining with imputed data (mm = micromobility). The number of chains analyzed (*n*) is 35,623.

Chain typology based on mode use	Start with mm	Has mm	Start with car	Non-car Owner	Mean walk (%)	Mean mm (%)	Mean car (%)	Mean transit mm (%)	Mean number of stops	Mean Distance (miles)	Share of the chain (%)
1	no	no	no	no	91%	0%	7%	2%	1.7	2.8	14%
2	no	no	no	yes	92%	0%	3%	5%	1.7	3.3	17%
3	no	no	yes	no	16%	0%	83%	0%	2.9	17.1	33%
4	no	yes	no	no	57%	32%	7%	36%	3	8.3	3%
5	no	yes	no	yes	57%	31%	5%	39%	3.4	10.1	8%
6	no	yes	yes	no	32%	24%	41%	26%	5.2	19.7	2%
7	yes	yes	no	no	32%	57%	10%	58%	2.5	7.6	5%
8	yes	yes	no	yes	38%	54%	6%	57%	2.5	6.7	11%

Chain typology based on mode use	Start with mm	Has mm	Start with car	Non-car Owner	Mean walk (%)	Mean mm (%)	Mean car (%)	Mean transit mm (%)	Mean number of stops	Mean Distance (miles)	Share of the chain (%)
*9**	*no*	*no*	*yes*	*yes*	*27%*	*0%*	*70%*	*2%*	*2.9*	*15.7*	*5%*
*10**	*no*	*yes*	*yes*	*yes*	*33%*	*26%*	*35%*	*31%*	*4.5*	*17.5*	*2%*

Note: *Type 9 and Type 10 chains represent occurrences of non-car owners starting a trip chain with a non-personal car, such as ridehail or taxi. The definition of cars used in the imputed dataset is described in the methods section.

Results from the same analyses with the imputed dataset show slightly different mode share compositions (Table 4). Most of the chain types used with imputed data show higher percentages of walk trips than subset data. Overall, the proportion of cars in the imputed dataset is higher in most of the chain types as these data include car-share, taxi, ridehail, etc. within the personal car category. Mode share for transit is lower in all types of chains with the imputed data compared to the subset data. However, the overall findings remain the same with both imputed and subset datasets: both direct and indirect effects of micromobility services are replacing car trips in trip chains. Overall, the results of our analysis on the influence of micromobility services on entire days of travel suggest a greater environmental sustainability potential for micromobility services by replacing car use.

Trip Chain Complexity Analysis

The results of car and micromobility use in complex chains are outlined in Table 5 (subset data) and Table 7 (imputed data) for car owners. For non-car owners, micromobility use in complex chains is outlined in Table 6 (subset data) and Table 8 (imputed data). For car owners, results show that more than 90% of the car-owner trip chains consist of three types of chains: chains that only have a primary purpose and are denoted “h-p-h”, chains that only have secondary purposes (i.e., any activities other than work or school) and denoted “h-s-h”, and chains that start with a primary activity then secondary activities before returning home and are denoted “h-p-s-h”. Approximately three-quarters of the chains consist of only secondary purposes (i.e., h-s-h), which are simple in nature with varying lengths.

Although most chains that only include secondary activities (i.e., “h-s-h”) have a very high car trip share, the rate is much less with the presence of micromobility services. The portions of “h-s-h” chains with micromobility are only about 4% to 7%. A similar pattern is seen for trip chains that only have work stops (i.e., “h-p-h”). In addition, on chains with only secondary activities, when micromobility is used with cars, the chains tend to be longer and have more stops than when micromobility is not used at all. This implies that micromobility services, in combination with car use, are enabling individuals to perform more activities within a simple non-work chain.

The case of chains that have both work and non-work trips (which are complex in nature) shows a slightly different pattern. We observed greater walking and transit use along with micromobility use with lower car use in these chains, indicating the indirect effect of micromobility on car trip replacement in the chain (in both imputed and subset data). This may be due to the travelers becoming more multimodal (i.e., using a combination of modes such as walking, micromobility, and transit) and replacing car use while traveling between primary activities and secondary activities in a chain. In the case of complex chains that start with a car trip, in both imputed and subset data, the share of car trips is approximately 50% less in chains with micromobility compared to chains without micromobility.

In most types of chains, we observe that the chain lengths are longer when the chain starts with a personal car and has micromobility trips compared to chains without micromobility. These chains likely consist of both shorter (less than a mile in length) and longer length (more than a mile in length) trips. On the other hand, chains that do not start with a personal car and have micromobility are much shorter in length compared to the other chains. These chains likely mainly consist of shorter (less than a mile in length) trips.

Non-car owners and car owners perform simple and complex chains at similar rates (Table 6 and Table 8). This indicates that micromobility users are performing complex chains using micromobility services in combination with other modes without having a personal car. Our findings support our initial hypothesis that micromobility can assist its users to perform complex chains without being reliant on personal cars.

Table 5. Results of trip chaining complexity based on an analysis of travel purposes within subset data for car owners (mm = micromobility). The number of chains analyzed (*n*) is 9,470. Chain categories listed in Table 2 with proportions less than (1%) for car owners are not reported here.

Chain Type	Start with mm	Has mm	Start with car	Mean walk* (%)	Mean mm* (%)	Mean car* (%)	Mean transit mm* (%)	Mean stops	Mean distance (miles)	Share of the Chain (%)
h-p-h	no	no	yes	6%	0%	89%	1%	2.6	17.6	4.87%
	no	yes	no	21%	26%	2%	65%	2.2	10.0	0.43%
	yes	yes	no	25%	66%	2%	71%	2.2	6.0	2.58%
	no	yes	yes	13%	38%	38%	49%	2.3	23.2	0.16%
h-p-s-h	no	no	yes	9%	0%	85%	0%	4.1	24.5	2.68%
	no	yes	no	30%	26%	3%	55%	3.5	11.4	0.22%
	yes	yes	no	38%	47%	8%	51%	3.8	9.8	1.02%
	no	yes	yes	14%	26%	40%	40%	4.0	30.5	0.10%
h-p-s-p-h	no	no	yes	15%	0%	75%	3%	4.5	19.7	0.71%
	no	yes	no	37%	27%	3%	51%	4.0	13.0	0.15%
	yes	yes	no	46%	39%	3%	45%	4.3	9.8	0.38%

Chain Type	Start with mm	Has mm	Start with car	Mean walk* (%)	Mean mm* (%)	Mean car* (%)	Mean transit mm* (%)	Mean stops	Mean distance (miles)	Share of the Chain (%)
	no	yes	yes	26%	36%	37%	36%	4.0	31.0	0.05%
h-s-h	no	no	yes	5%	0%	93%	0%	3.0	15.0	35.26%
	no	yes	no	33%	25%	2%	44%	3.5	16.1	0.86%
	yes	yes	no	30%	62%	3%	63%	2.7	4.4	5.41%
	no	yes	yes	21%	31%	44%	33%	3.8	21.9	0.45%
h-s-p-h	no	no	yes	5%	0%	91%	0%	3.8	26.6	0.82%
	no	yes	no	44%	29%	0%	45%	3.7	11.5	0.03%
	yes	yes	no	41%	48%	3%	52%	4.0	4.8	0.27%
	no	yes	yes	11%	35%	45%	41%	4.0	26.3	0.05%
h-s-p-s-h	no	no	yes	9%	0%	86%	0%	6.0	31.6	0.87%
	no	yes	no	51%	20%	1%	34%	6.2	12.1	0.12%
	yes	yes	no	43%	38%	5%	48%	5.2	9.0	0.21%
	no	yes	yes	16%	28%	38%	43%	6.8	23.9	0.08%

Note: *These columns indicate the mean percentages of that mode's presence on that specific type of chain

Table 6. Results of trip chaining complexity based on an analysis of travel purposes within subset data for zero-car owners (mm = micromobility). The number of chains analyzed (*n*) is 6,515. Chain categories listed in Table 2 with proportions less than (1%) for zero-car owners are not reported here.

Chain Type	Start with mm	Has mm	Mean walk* (%)	Mean mm* (%)	Mean transit mm* (%)	Mean stops	Mean distance (miles)	Share of the Chain (%)
h-p-h	no	no	46%	0%	26%	2.1	8.2	6.05%
	no	yes	17%	29%	67%	2.4	10.9	1.01%
	yes	yes	22%	70%	75%	2.3	5.4	5.05%
h-p-s-h	no	no	49%	0%	24%	3.7	11.9	2.12%
	no	yes	32%	23%	55%	3.7	13.5	0.58%
	yes	yes	38%	54%	58%	3.7	7.0	1.80%
h-p-s-p-h	no	no	61%	0%	22%	4.5	14.4	1.24%
	no	yes	40%	23%	53%	4.1	17.9	0.15%

Chain Type	Start with mm	Has mm	Mean walk* (%)	Mean mm* (%)	Mean transit mm* (%)	Mean stops	Mean distance (miles)	Share of the Chain (%)
	yes	yes	48%	39%	45%	4.6	8.6	0.61%
h-s-h	no	no	75%	0%	7%	2.5	4.8	53.86%
	no	yes	29%	28%	53%	3.3	10.9	2.93%
	yes	yes	30%	62%	66%	2.7	5.6	19.88%
h-s-p-h	no	no	53%	0%	20%	3.5	11.5	0.75%
	no	yes	35%	22%	40%	4.0	14.0	0.12%
	yes	yes	38%	47%	60%	3.4	8.3	0.68%
h-s-p-s-h	no	no	40%	0%	17%	5.6	11.7	0.51%
	no	yes	46%	23%	33%	6.2	15.1	0.15%
	yes	yes	42%	41%	45%	5.3	11.0	0.51%

Note: *These columns indicate the mean percentages of that mode's presence on that specific type of chain

Table 7. Results of trip chaining complexity based on an analysis of travel purposes within imputed data for car owners (mm = micromobility). The number of chains analyzed (*n*) is 20,300. Chain categories listed in Table 2 with proportions less than (1%) for car owners are not reported here.

Chain Type	Start with mm	Has mm	Start with car	Mean walk* (%)	Mean mm* (%)	Mean car* (%)	Mean transit mm* (%)	Mean stops	Mean distance (miles)	Share of the Chain (%)
h-p-h	no	no	yes	13%	0%	87%	0%	1.1	12.7	2.50%
	no	yes	no	55%	37%	5%	40%	1.1	5.9	0.59%
	yes	yes	no	26%	70%	4%	70%	1.1	4.6	1.15%
	no	yes	yes	30%	33%	35%	35%	1.1	8.3	0.19%
h-p-s-h	no	no	yes	20%	0%	78%	1%	3.1	18.7	1.56%
	no	yes	no	61%	27%	9%	31%	3.3	9.7	0.39%
	yes	yes	no	40%	42%	16%	43%	3.0	9.4	0.62%
	no	yes	yes	34%	24%	39%	27%	2.9	20.3	0.19%
h-s-h	no	no	yes	15%	0%	84%	0%	2.9	16.9	49.07%
	no	yes	no	56%	33%	7%	36%	3.1	8.0	3.51%
	yes	yes	no	30%	59%	11%	59%	2.4	7.6	6.40%
	no	yes	yes	31%	24%	42%	26%	5.8	19.7	2.72%

Chain Type	Start with mm	Has mm	Start with car	Mean walk* (%)	Mean mm* (%)	Mean car* (%)	Mean transit mm* (%)	Mean stops	Mean distance (miles)	Share of the Chain (%)
h-s-p-h	no	no	yes	18%	0%	81%	0%	3.2	21.2	0.75%
	no	yes	no	60%	33%	3%	36%	2.7	7.9	0.16%
	yes	yes	no	44%	49%	6%	50%	3.0	5.2	0.20%
	no	yes	yes	29%	23%	45%	25%	3.6	25.4	0.10%
h-s-p-s-h	no	no	yes	25%	0%	74%	1%	6.5	30.4	1.01%
	no	yes	no	61%	26%	9%	30%	5.9	12.8	0.37%
	yes	yes	no	45%	39%	14%	41%	6.3	12.4	0.33%
	no	yes	yes	40%	18%	38%	22%	6.5	27.1	0.25%

Note: *These columns indicate the mean percentages of that mode's presence on that specific type of chain

Table 8. Results of trip chaining complexity based on an analysis of travel purposes within imputed data for zero-car owners (mm = micromobility). The number of chains analyzed (*n*) is 15,323. Chain categories listed in Table 2 with proportions less than (1%) for zero-car owners are not reported here.

Chain Type	Start with mm	Has mm	Mean walk* (%)	Mean mm* (%)	Mean transit mm* (%)	Mean stops	Mean distance (miles)	Share of the Chain (%)
h-p-h	no	no	71%	0%	7%	1.1	5.1	1.47%
	no	yes	53%	35%	40%	1.2	6.2	1.10%
	yes	yes	28%	67%	69%	1.1	3.7	2.60%
h-p-s-h	no	no	68%	0%	10%	2.9	11.3	0.80%
	no	yes	57%	27%	36%	3.1	11.0	0.98%
	yes	yes	45%	46%	49%	2.9	7.2	1.24%
h-p-s-p-h	no	no	80%	0%	5%	3.0	6.9	0.19%
	no	yes	64%	23%	30%	3.2	10.6	0.16%
	yes	yes	55%	42%	43%	3.3	5.0	0.27%
h-s-h	no	no	78%	0%	3%	2.0	5.8	43.02%

Chain Type	Start with mm	Has mm	Mean walk* (%)	Mean mm* (%)	Mean transit mm* (%)	Mean stops	Mean distance (miles)	Share of the Chain (%)
	no	yes	52%	30%	37%	3.8	11.7	17.19%
	yes	yes	38%	54%	57%	2.7	7.0	18.63%
h-s-p-h	no	no	71%	0%	10%	3.0	10.2	0.53%
	no	yes	49%	29%	39%	3.5	11.6	0.67%
	yes	yes	46%	47%	49%	2.7	8.4	0.55%
h-s-p-s-h	no	no	68%	0%	10%	6.1	16.5	0.76%
	no	yes	59%	23%	32%	7.3	18.9	0.97%
	yes	yes	46%	46%	49%	5.7	9.8	0.71%

Note:
*These columns indicate the mean percentages of that mode's presence on that specific type of chain

In the analysis with the imputed dataset, in most cases, a reduction in the average trip chain distance is observed compared to the subset data. In addition, a reduction in the transit mode share in most trip chain types is observed. In some chains, micromobility trip share is greater while, in others, it is smaller compared to the subset data. Walk share in trip chains was greater in most types of trip chains compared to subset data. Overall, findings are similar for subset and imputed data.

Conclusion

This study explores the trip-chaining patterns of micromobility users using travel diary data of individuals collected from 48 cities across the US to understand the sustainability potential of micromobility services. Generally, when a trip chain starts with a personal car, people tend to use the car to perform most of the trips in a chain. However, we found that the presence of micromobility services along a trip chain that starts with a car is associated with much less car use. This may be a result of replacing car trips by using micromobility services, in combination with other modes, to perform various trips in the middle of the chain. These types of chains are longer and have multiple activities involved. With very few exceptions, we found that personal cars were replaced with other modes as car owners left their cars at home after planning to use micromobility. This suggests that, for a subset of users, micromobility can form part of a car-free or car-light day of travel even when a personal car is available.

We found that trip chains with less car use utilized a variety of different modes in combination with micromobility services. This indicates the potential of micromobility services to nudge people towards multimodality. All these findings suggest both direct and indirect effects of micromobility services on car use, which previous studies have ignored or understated due to their focus on the trip level. Our analyses show that, for micromobility users, complex chains made by car owners are not entirely dominated by car trips. Instead, car owners who use micromobility services generally use their cars less on both simple and complex chains.

Overall, our findings show that it is important to consider chains of trips—rather than individual trips—while analyzing the car replacement potential of micromobility services. Future studies can conduct more detailed analyses with these data and other travel diary data collected from both micromobility users and non-users to expand our understanding of the sustainability potential of micromobility services.

References

Currie, G., and Delbosc, A. (2011). Exploring the trip chaining behaviour of public transport users in Melbourne. *Transport Policy*, *18*(1), 204–210. https://doi.org/10.1016/J.TRANPOL.2010.08.003

Federal Highway Administration. (2009). *Number of Vehicle Trips by Trip Distance*. https://nhts.ornl.gov/tables09/fatcat/2009/vt_TRPMILES.html. Retrieved September 8, 2024.

Federal Highway Administration. (2017). *National Household Travel Survey 2017*. https://doi.org/10.4135/9781483346526.n341

Fishman, E., Washington, S., and Haworth, N. (2013). Bike Share: A Synthesis of the Literature. In *Transport Reviews* (Vol. 33, Issue 2, pp. 148–165). Routledge. https://doi.org/10.1080/01441647.2013.775612

Fitch-Polse, D. T., Mohiuddin, H., Fukushige, T., Darr, J., and Agarwal, S. (2023). *American Micromobility Panel: Part 1*. https://doi.org/10.7922/G2F47MG3

Hensher, D. A., and Reyes, A. J. (2000). *Trip chaining as a barrier to the propensity to use public transport*.

Huang, Y., Gao, L., Ni, A., and Liu, X. (2021). Analysis of travel mode choice and trip chain pattern relationships based on multi-day GPS data: A case study in Shanghai, China. *Journal of Transport Geography*, *93*. https://doi.org/10.1016/j.jtrangeo.2021.103070

Li, Z., Wang, W., Yang, C., and Jiang, G. (2013). Exploring the causal relationship between bicycle choice and trip chain pattern. *Transport Policy*, *29*, 170–177. https://doi.org/10.1016/J.TRANPOL.2013.06.001

Liu, L., and Miller, H. J. (2022). Measuring the impacts of dockless micro-mobility services on public transit accessibility. *Computers, Environment and Urban Systems*, *98*, 101885. https://doi.org/10.1016/J.COMPENVURBSYS.2022.101885

Mcguckin, N. and Nakamoto, Y.(2004). *Trips, Chains and Tours-An Operational Definition*.

Mohiuddin, H. (2021). Planning for the First and Last Mile: A Review of Practices at Selected Transit Agencies in the United States. *Sustainability 2021, Vol. 13, Page 2222*, *13*(4), 2222. https://doi.org/10.3390/SU13042222

NACTO. 2022. “HALF A BILLION TRIPS.” Retrieved August 21, 2024 (https://nacto.org/wp-content/uploads/2022/12/2020-2021_shared_micro_snapshot_Dec7_2022.pdf).

NACTO. 2023. “Shared Micromobility in 2022.” Retrieved August 21, 2024 (https://nacto.org/publication/shared-micromobility-in-2022/)

NACTO. 2024. “Shared Micromobility in 2023.” Retrieved August 6, 2024 (https://nacto.org/publication/shared-micromobility-in-2023/).

National Association of City Transportation Officials. 2020. “Shared Micromobility in the U.S.: 2019.” Retrieved October 11, 2020 (https://nacto.org/shared-micromobility-2019/).Primerano, F., Taylor, M. A. P., Pitaksringkarn, L., and Tisato, P. (2008). Defining and understanding trip chaining behaviour. *Transportation*, *35*(1), 55–72. https://doi.org/10.1007/S11116-007-9134-8/TABLES/7

RSG (2022). *rMove App. https://rsginc.com/rmove/*

Schlich, R., and Axhausen, K. W. (2003). Habitual travel behaviour: Evidence from a six-week travel diary. *Transportation*, *30*(1), 13–36. https://doi.org/10.1023/A:1021230507071

Schneider, F., Ton, D., Zomer, L. B., Daamen, W., Duives, D., Hoogendoorn-Lanser, S., and Hoogendoorn, S. (2021). Trip chain complexity: a comparison among latent classes of daily mobility patterns. *Transportation*, *48*(2), 953–975. https://doi.org/10.1007/S11116-020-10084-1/TABLES/3

Shaheen, S., and Chan, N. (2016). Mobility and the sharing economy: Potential to facilitate the first-and last-mile public transit connections. *Built Environment*, *42*(4), 573–588. https://doi.org/10.2148/benv.42.4.573

Vij, A., Carrel, A., and Walker, J. L. (2013). Incorporating the influence of latent modal preferences on travel mode choice behavior. *Transportation Research Part A: Policy and Practice*, *54*, 164–178. https://doi.org/10.1016/J.TRA.2013.07.008

Yang, L., Shen, Q., and Li, Z. (2016). Comparing travel mode and trip chain choices between holidays and weekdays. *Transportation Research Part A: Policy and Practice*, *91*, 273–285. https://doi.org/10.1016/J.TRA.2016.07.001

Ye, X., Pendyala, R. M., and Gottardi, G. (2007). An exploration of the relationship between mode choice and complexity of trip chaining patterns. *Transportation Research Part B: Methodological*, *41*(1), 96–113. https://doi.org/10.1016/J.TRB.2006.03.004