Integration of Daily Travel and Interregional Travel – A Classification of Travelers

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16. Abstract

Interregional travel denotes the short-haul component of long-distance travel (LDT) and represents the domestic LDT in the United States. The development of an integrated travel demand model to combine daily travel and interregional travel has begun to gain attention from transportation researchers. However, daily travel and interregional travel/LDT were treated separately or partially connected in travel demand modeling. The integration of two travel markets requires the examination of activity arrangement. Furthermore, few studies have explored the activity arrangement associated with these two travel markets or expanded the discussion beyond leisure travel. This study examines the activity arrangement associated with daily travel and interregional travel. This study applies cluster analysis to represent the purpose complexity of trip chains and develop latent classes of travelers to capture how people arrange activities associated with daily travel and interregional travel. Results of this study show five clusters that reflect the purpose complexity of daily travel trip chains and four clusters that present the purpose complexity of interregional travel trip chains. This study identifies six latent travelers classes, representing how people organize activities associated with daily and interregional travel. Results show that gender, employment status, vehicle ownership, age, and household income affect class membership. Additionally, other sociodemographic and living environment variables vary across different latent classes. Findings from this study provide useful insights for understanding activity

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Acknowledgements *(if desired)*

All text should appear as it does in this paragraph. The CM2 consortium will build legal, governmental, technical, and analytical frameworks for megaregion transportation planning. Our center supports research that establishes a legal framework for cooperative megaregion transportation planning; develops analytical framework targeting passenger and freight mobility improvement in megaregions; capitalizes access-enabling spatial strategies; promotes equity for elderly and rural populations in and around the megaregion; creates environmental justice metrics in the megaregion context; improves public participation at the megaregional scale; optimizes multi-modality and inter-modality; and develops a GIS-based planning support system for cooperative mobility in megaregions.

Paragraphs should be spaced as they are in this section. The consortium of Cooperative Mobility for Competitive Megaregions (CM2) aims to advance research, education, and technology transfer initiatives to improve the mobility of people and goods in urban and rural communities of megaregions.

Table of Contents (this can populate automatically with "CM^2" formatting styles)

Executive Summary *(if desired)*

Text should begin here. Transit-oriented development (TOD) has been largely the practice of local communities and transit agencies, but few have explored TOD opportunities and challenges from a regional perspective. This research aims to fill the gap, with a focus on the Texas Triangle megaregion.

Chapter 1. Chapters without Headings or Subheadings

Text should begin here. In December of 2016, the United States Department of Transportation (USDOT) awarded The University of Texas at Austin a five-year grant to lead a consortium under the University Transportation Centers (UTC) program. CM^2's consortium partners include The University of Texas at Austin, Louisiana State University, Texas Southern University, and the University of Pennsylvania, with affiliates at Cornell University and Rutgers University. CM^2 is a designated Tier 1 University Transportation Center.

Text. The coordination of planning for megaregions challenges established planning practices by disregarding boundaries of governance. Not only do megaregions encompass multiple cities and counties, but many also encompass several states, all of which must work collectively to manage a competitive megaregion.[1] The Tier 1 United States Department of Transportation (USDOT) University Transportation Center (UTC) for Cooperative Mobility for Competitive Megaregions (CM^2) aims to foster cooperative, research-driven coordination of transportation planning in these megaregions.[2]

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Chapter 2. Chapters with Headings or Subheadings

2.1. First Heading

Text. America's metropolitan regions are expanding at a rapid pace. As these regions grow, they connect and overlap with their neighboring regions until the boundaries between regions are no longer clear. Already, one may find it challenging to draw a boundary between the New York and Philadelphia metropolitan regions, or between the San Diego and Los Angeles metropolitan regions. This new scale of geography is known as the megaregion.

2.2. Second Heading

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2.2.2. Second Subheading

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2.3. Third Heading

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Text. Technology transfer is an essential element of our consortium's work to move research into practice. Each consortium institution has significant technology transfer experience. Whether through the Center for Sustainable Development or the Center for Transportation Research (UT-Austin), the Center for Transportation Training and Research (TSU), the Gulf Coast Center for Evacuation and Transportation Resiliency (LSU), or the Penn Institute for Urban Research…

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Figure 2.1. Cooperative Mobility for Competitive Megaregions, a Tier-1 USDOT UTC

Chapter 3. Conclusion and Recommendations

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Appendix A: Additional Matters at the End of the Report

1. Headings Should Not Be Included in the Table of Contents

However, references should be included in the reference section which follows. Appendices can be formatted in any consistent format. Graduate Research Assistants at CM^2 have been sharing their research through a monthly brown bag series at the University of Texas at Austin. Students organize talks to present their work and findings and host an informal discussion with other students and professors. The brown bag series is a way to hone student's presentation skills and key research points, as well as provide an open platform for feedback on research methods and design. The students who have presented their work thus far are listed on the Education page under Monthly Brown Bag Series.[5]

1.1 Subheadings May Be Utilized

Text. The CM^2 Summer Forum brought together the consortium of institutions that represent the Tier 1 University Transportation Center: the University of Pennsylvania, the University of Texas at Austin, Texas Southern University, and Louisiana State University.

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ABSTRACT

Interregional travel denotes the short-haul component of long-distance travel (LDT) and represents the domestic LDT in the United States. The development of an integrated travel demand model to combine daily travel and interregional travel has begun to gain attention from transportation researchers. However, daily travel and interregional travel/LDT were treated separately or partially connected in travel demand modeling. The integration of two travel markets requires the examination of activity arrangement. Furthermore, few studies have explored the activity arrangement associated with these two travel markets or expanded the discussion beyond leisure travel. This study examines the activity arrangement associated with daily travel and interregional travel. This study applies cluster analysis to represent the purpose complexity of trip chains and develop latent classes of travelers to capture how people arrange activities associated with daily travel and interregional travel. Results of this study show five clusters that reflect the purpose complexity of daily travel trip chains and four clusters that present the purpose complexity of interregional travel trip chains. This study identifies six latent travelers classes, representing how people organize activities associated with daily and interregional travel. Results show that gender, employment status, vehicle ownership, age, and household income affect class membership. Additionally, other sociodemographic and living environment variables vary across different latent classes. Findings from this study provide useful insights for understanding activity arrangements associated with daily travel and interregional travel and assist in developing integrated travel demand models.

Keywords: Interregional travel; Activity arrangement; National Household Travel Survey

INTRODUCTION

Long-distance travel (LDT) (typically defined as a one-way trip longer than 50 miles across multiple regions or metropolitan areas) has been studied extensively in the field of travel demand. It refers to travel that may cover considerable distances, often spanning multiple regions or countries; thus, it is treated separately from daily travel that predominantly occurs within a metropolitan area (*1*). As people's activities in distant locations continue to grow, LDT becomes more routine. Scholars have called for improvements in current methods of travel demand analysis by integrating LDT and daily travel (*2–6*). This interest in combining two travel markets in travel demand analysis has led to extensive studies. Studies demonstrate the interrelationship between these two travel markets (*7–13*). However, daily travel and LDT were treated separately or partially connected in demand modeling, which is insufficient (*5*, *6*, *14*, *15*, *15–17*).

Analyzing the integration of daily travel and interregional travel markets should take into consideration the activity arrangement associated with these two travel markets. However, current studies largely compare the activity arrangement between weekday and weekend travel, and no research has focused on daily travel and LDT (*18*, *19*). Additionally, existing studies focusing on activity arrangement and participation are for leisure travel, which does not consider all purposes to reflect the purpose complexity of LDT (*3*, *20*, *21*). Given the inadequacy of current studies, further research is needed to better understand the activity participation associated with daily travel and LDT and to assist in the integration of both travel markets in travel demand modeling (*2–4*).

As the average travel distance becomes longer and LDT increases, there is a need to pay special attention to the short-haul component of LDT, interregional travel (*22*) that represent the domestic LDT in the U.S. This study defines interregional travel as a one-way trip in the distance range of 50–600 miles or a round trip in the distance range of 100–1200 miles. This study aims to expand the integrated travel demand model by exploring the activity arrangement associated with daily travel and interregional travel. This is achieved by developing clusters to represent the purpose complexity associated with these two travel markets and deriving travelers' latent classes based on daily travel and interregional travel-making patterns. This study aims to answer the following research questions:

- What is the purpose complexity of daily and interregional travel trip chains?
- How do people arrange activities associated with daily travel and interregional travel?

After the introduction, the paper reviews related literature. Next, the paper introduces data from the 2001 National Household Travel Survey (NHTS), the conceptual framework, and the analytical approach used for the study. Analysis results and findings are then presented. The discussions and conclusions end this study.

LITERATURE REVIEW

As few studies have focused on interregional travel, this section reviews the literature on LDT, which brings insights to this study. LDT is usually treated as a stand-alone travel market or independent travel purpose that is separated from short-distance travel in travel demand modeling efforts by agencies (*14*–*17*). However, short-distance travel and LDT are both vital for travelers, and they are related. It was found that residents in large cities and high-density neighborhoods had more and longer LDT and shorter travel in daily life than those living in small and low-dense areas (*10*). It was summarized by a comprehensive literature review that the increased LDT might or might not offset the concurrent decrease in daily travel, and the results varied across studies (*8*). Berliner et al. (*7*) found that those who made short-distance trips by bike had a higher number of long-distance trips by air. Similarly, Magdolen et al. (*12*) presented that people who had similar daily travel behavior might behave differently in LDT. Magdolen et al. (*11*) derived the latent groups of urban people with a focus on leisure travel. They found that one group of people conducted daily travel environmentally friendly, but they had the most tourist LDT and air travel. It was also found in another study that travelers who had more sustainable transportation mode use in daily life could have more sustainable leisure LDT, and both were predictable by travelers' habits (*9*). Reichert et al. (*13*) found that residents living in cities with large populations generated more emissions for LDT and less emissions for daily travel compared to residents living in small cities.

In addition to the exploratory analysis of the comparison between LDT and short-distance travel, limited modeling efforts were made for the integrated prediction of LDT and daily travel, and most of them were trip-based analyses. Limited research has focused on integrating LDT and daily/short-distance travel. Llorca et al. (*5*) combined a macroscopic model and an agent-based model. The integration model structure provided better model output than the single one in terms of daily traffic volumes. Stefan et al. (*6*) developed a combined long- and short-distance travel demand model for California state. In the modeling structure, the demand models for two travel markets were actually independently established, and the relationship was mainly reflected in how travelers chose between short-distance travel or LDT. Erhardt et al. (*15*) had more interactions between short-distance travel and LDT in the sense that the short-distance travel model fed the output as a measurement of accessibility in the binary choice of whether or not to engage in LDT for two weeks. Given the great importance of the interconnection between daily travel and LDT, the current research focusing on integrating both travel markets in travel demand analysis seems insufficient. As travel is a kind of "derived demand" (*23*), more research on the activity arrangement of daily travel and LDT should be considered (*2*–*4*).

Nevertheless, current studies largely compare the activity arrangement between weekday and weekend travel, which does not extend to the comparison between different travel markets based on travel distance, i.e., daily short-distance travel and LDT. For example, Lockwood et al. (*18*) compared activity-travel characteristics between weekday and weekend travel markets. They found large discrepancies between these two travel markets regarding activity organization patterns. Nayak and Pandit (*19*) demonstrated that the inclusion of interdependencies in the activity participation patterns of two travel

markets could improve the prediction accuracy of daily activity patterns compared to a single market modeling framework. Similarly, considering the interrelationship between activity participation patterns associated with daily travel and LDT might also benefit the integrated travel demand modeling framework. However, to the authors' knowledge, no study has explored this interrelationship. Additionally, activity arrangement and participation analysis are mainly for leisure travel and not extended to all purposes of LDT to consider the purpose complexity of LDT (*20*, *24*). For example, studies examined the leisure activity participation loyalty across daily and LDT travel markets, which led to a combined framework derived to start with time use and participation for travel demand modeling (*3*, *21*).

Overall, the current practice of integrating daily travel and interregional travel/LDT has been inadequate. This study attempts to lay the foundations for an integrated travel demand model by exploring the purpose complexity associated with daily travel and interregional travel and examining the classification of travelers.

METHODS

Data

There are eight nationwide travel surveys in the U.S., including Nationwide Personal Transportation Survey (NPTS) conducted in 1969, 1977, 1983, 1990, and 1995, and NHTS in 2001, 2009, and 2017 (*25*). They present the demographic characteristics of surveyed individuals and their respective households. Each survey year contains one or two data files related to travel. Each survey year has a daily trip file that collects all short-distance daily travel and activities made by surveyed individuals on assigned travel days (within 24 hours). The 1969, 1977, 1983, 1990, 1995, and 2001 NPTS/NHTS surveys also include a period trip file to collect information on nationwide LDT. The 1969 NPTS, the earliest survey in the data series, collects long-distance trips as overnight travel. In 1977, 1983, 1990, and 1995 NPTS, long-distance trips with the farthest point over 75 miles from home during the preceding 14 days are collected. In the 2001 NHTS, the survey collects long-distance trips over 50 miles from home during the preceding 28 days. In the 2017 NHTS, six add-on agencies specifically collect information on long-distance trips using additional questions for residents' trips over 50 or 75 miles during the previous eight weeks (*26*). Among the surveys that comprise an LDT survey, the 2001 NHTS is the only one that records up to four activity purposes, with the main purpose ranked first. Although the 1995 ATS records LDT across a year, it excludes the commute travel purpose and does not have a short-distance daily portion. The 2001 NHTS is the latest nationwide survey containing both LDT and daily travel portions and is used in this study.

This study uses trip chains as the unit of analysis to describe daily travel and interregional travel. The 2001 NHTS period file provides long-distance trip chains in a home–activities–home round trip format and is analyzed directly. This study focuses on the short-haul component of LDT, interregional

travel, in the two-way distance range of 100–1200 miles. The 2001 NHTS daily file provides individuals' daily travel in trip format. The daily trip chains are generated by linking trips, which include those that start and end at home and those with either end at home. They can be home–activities–home, activities–home, or home–activities trip chains. This study defines daily travel as a one-way trip chain of less than 50 miles or a round-trip chain of less than 100 miles. **Table 1** reports the summary statistics of the sample. It should be noted that travelers are those who report both daily and interregional travel information in the 2001 NHTS.

Table 1 Descriptive Statistics

Average activity participation shares within daily trip chain	**min**	**max**	**mean**	**std**
Work-related	0	1	0.176	0.347
School/church	0	1	0.124	0.311
Shopping/errands	0	1	0.349	0.422
Social/recreational	0	1	0.204	0.369
Other	0	1	0.148	0.310
Average activity duration shares within daily trip chain				
Work-related	0	1	0.215	0.399
School/church	0	1	0.137	0.334
Shopping/errands	0	1	0.309	0.434
Social/recreational	0	1	0.216	0.391
Other	0	1	0.123	0.307
Number of observations	**208,837**			
Average activity participation probability within interregional trip chain	**min**	**max**	**mean**	**std**
Work-related	0	1	0.289	0.453
School/church	0	1	0.035	0.184
Shopping/errands	0	1	0.092	0.288
Social/recreational	0	1	0.497	0.500
Other	0	1	0.160	0.367
Number of observations	**40,950**			
Traveler	**min**	**max**	**mean**	**std**
Age/100	0.050	0.880	0.409	0.193
ln(Adjusted income)/10 (Income is adjusted by gas	0.711	1.142	1.047	0.069
Gender: 1: Male; 0: Otherwise	0	1	0.495	0.500
Employment status: 1: Have work; 0: Otherwise	0	1	0.640	0.480
Vehicles per person in household	0	10	0.904	0.521
MSA status: Live in an MSA with population of less than 250,000	0	1	0.091	0.288

MSA status: Live in an MSA with population of 250,000-499,999	0	1	0.087	0.282
MSA status: Live in an MSA with population of 500,000-999,999	0	1	0.075	0.264
MSA status: Live in an MSA with population of 1,000,000-2,999,999	0	1	0.202	0.401
MSA status: Live in an MSA with population of 3,000,000+	0	1	0.276	0.447
MSA status: Not live in MSA	0	1	0.269	0.443
Urban area status: live in urban area	0	1	0.724	0.447
Urban area status: not live in urban area	0	1	0.276	0.447
Education level 1: < high school or GED (General Educational Development)	0	1	0.439	0.496
Education level 2: some college or associate degree	0	1	0.245	0.430
Education level 3: bachelor's degree	0	1	0.177	0.382
Education level 4: graduate degree or professional degree	0	1	0.140	0.347
Driver status: 1: Have driver's license; 0: Otherwise	0	1	0.840	0.367
Life cycle status: one or more adults, not retired, youngest children 0–21	0	1	0.536	0.499
Life cycle status: one or more adults, retired or not retired, no children	0	1	0.464	0.499
Number of observations	**15,497**			

Conceptual Framework

According to the consumer behavior theory, travel is derived from the need to move from one place to another as a type of "derived demand" (*23*). As the distance to the main destination increases, individuals are more likely to chain activities together to save on travel costs and avoid making separate round trips, leading to the formation of complex trip chains (*27–29*). The development of activity-based or trip-chain-based integrated daily travel and interregional travel demand models is grounded on the activity arrangement patterns associated with daily and interregional travel trip chains. This study proposes a framework to illustrate how people allocate activities to travel markets and conduct travel to meet these activity needs (**Figure 1**).

The first layer of the framework presents the time allocation among activities within a period. The allocation patterns usually vary between individuals. In this study, the final time distribution for activities is assumed to be static for each individual.

The second layer of the framework is the activity participation allocation between travel markets. Instead of treating interregional and daily travel in an isolated or partly combined way, this framework illustrates their relationship by allocating activities between these travel markets. Similar to time

allocation across activities, people need to determine within which travel market they will participate in these activities.

The third layer presents the derived travel demand to fulfill the activity needs. As the previous two layers illustrate how people allocate time across activities of various purposes and between travel markets, this layer shows how people organize these activities within two travel markets to form daily or interregional trip chains.

This study focuses on the third layer to explore the complexity of trip chains and explore how people conduct daily travel and interregional travel.

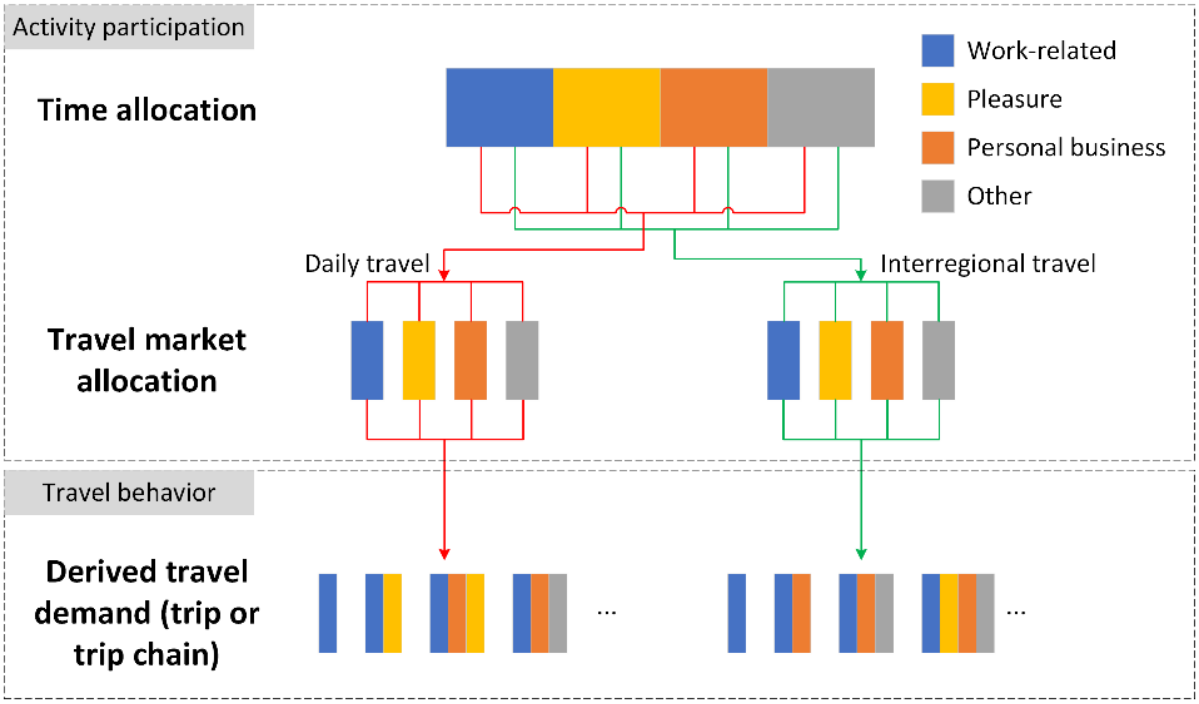

Figure 1 The activity pattern and characteristics of interregional travel

Analytical Approach

The complexity of daily travel and interregional trip chains is analyzed using the k-means cluster method. It is a common method to identify similar travel patterns by natural grouping (*12*, *30–32*). Specifically, complexity typology is developed based on activity participation characteristics. Commonly used characteristics for activity pattern recognition include durations, participation, and location of

activities (*32*, *33*). Given the data availability, variables used to develop complexity typology for daily travel include activity participation shares and activity duration shares of different purposes within trip chains, and variables used to obtain complexity typology for interregional travel include activity participation probabilities of different purposes within trip chains.

The travelers are then classified using a latent class analysis (LCA) (*34*, *35*).

This method groups people with similar activity participation patterns associated with daily travel and interregional travel into distinct classes. Compared to commonly used deterministic cluster analysis, the LCA is a model-based rather than a distance-based grouping of data. The group membership given by LCA is assigned probabilistically rather than deterministically (*11*, *36*). LCA estimates the probability of an individual i (with x_i as covariates) belonging to a latent class c ($c = 1,2, \dots, C$), $P(c|x_i)$, based on indicators, y_{ij}, which is denoted as a measurement model. The extension of the measurement model with active covariates contains class membership predictors. The entire model is denoted as the probability of having the vector of indicators $y_i = (y_{i1,}y_{i2}, \dots, y_{ij}, \dots, y_{iJ})$ and is formulated as:

$$P(y_i|x_i) = \sum_{c=1}^{C}(P(c|x_i) * \prod_{j=1}^{J} P(y_{ij}|c))$$

Indicators include frequencies of participating in different complexity clusters associated with daily travel and interregional travel and travel distance as a spatial indicator (*37*). The active covariates are those that have impacts on class membership, including age, adjusted income, gender, employment status, and vehicle ownership. Additional inactive covariates are analyzed to describe other sociodemographic and living environment characteristics. The analysis can draw insights into how individuals' activity arrangement between different travel markets is structured. To determine the optimal number of latent classes, the measurement models with indicators are estimated for 1–8 latent classes. This study compares the Consistent' Akaike's Information Criterion (CAIC) for selecting the optimal number of classes. With the best number of classes, the model with active covariates is estimated.

RESULTS

Aggregated characteristics analysis

The aggregated activity participation shares for different purposes are presented in **Table 2** for daily travel and interregional travel markets. The majority of daily travel and interregional travel is for single-purpose activity, within which daily travel is largely associated with leisure activities, including shopping/errands and social/recreational, and interregional travel is related to work or social/recreational activities. Multiple-purpose travel comprises substantial portions of daily travel (28.61%) and interregional travel (11.57%), demonstrating that people combine multiple activities to form multiple-

purpose travel. For multiple-purpose travel, work-related activities take up a smaller portion of interregional travel (11.54%) than of daily travel (37.09%), and social/recreational activities occupy a more proportion for interregional travel (60.22%) than for daily travel (40.77%). For multiple-purpose travel containing work-related activities, interregional trip chains are mainly associated with social/recreational activities (42.78%), while daily trip chains mostly connect to shopping/errands activities (69.24%). It indicates that people are willing to incorporate non-work trips into commuting travel, supporting the argument that the pure focus on the traditional work commute is in jeopardy (*38*).

Table 2 Activity shares associated with daily travel and interregional travel

Distance Range	Daily travel	Interregional travel
Frequency	208,837	40,950
Single purpose (%)	149,099 (71.39)	36,212 (88.43)
Work-related (%)	26,350 (17.67)	11,085 (30.61)
School/Church (%)	21,239 (14.24)	1,097 (3.03)
Shopping and Errands (%)	51,119 (34.29)	2,400 (6.63)
Social and Recreational (%)	32,216 (21.61)	16,538 (45.67)
Other (%)	18,175 (12.19)	5,092 (14.06)
Multiple purposes (%)	59,738 (28.61)	4,738 (11.57)
Work-related (%)	22,157 (37.09)	547 (11.54)
School/Church (%)	1,060 (4.78)	16 (2.93)
Shopping and Errands (%)	15,341 (69.24)	90 (16.45)
Social and Recreational (%)	4,240 (19.14)	234 (42.78)
Other (%)	8,366 (37.76)	109 (19.93)
School/Church (%)	10,799 (18.08)	192 (4.05)
Shopping and Errands (%)	45,368 (75.94)	507 (10.70)
Social and Recreational (%)	24,356 (40.77)	2,853 (60.22)
Other (%)	30,350 (50.81)	639 (13.49)

Trip chains cluster characteristics

The results from the k-means clustering can be found in **Figure 2–Figure** 4. The figures present the aggregated characteristics based on variables used in the clustering analysis. The following paragraphs summarize the activity participation patterns associated with each cluster for daily travel and interregional travel.

Cluster 1 (daily travel): School/church + shopping/errands. This cluster largely contains school/church activities with a relatively small portion of shopping/errands activities. Even though shopping/errands activities take 6.6% of activity participation, the average activity duration spent on these purposes is as low as 2.2%.

Cluster 2 (daily travel): Social/recreational + shopping/errands. Travel associated with this cluster is mainly for social/recreational activities. Shopping/errands activities take up 10.2%, but the average share of duration only contributes to 4.1%.

Cluster 3 (daily travel): Shopping/errands. Daily travel belonging to this cluster is mainly for shopping/errands activities and accounts for more than 90% of the total activity participation and activity duration.

Cluster 4 (daily travel): Other + shopping/errands. This cluster contains daily travel for other purposes. Trip chains with this purpose are the most likely to contain shopping/errands activities.

Cluster 5 (daily travel): Work-related + shopping/errands. This cluster is mainly made up of work-related activities that contribute to more than 90% of time spent. Work-related travel is most likely to be associated with shopping/errands activities.

Cluster 1 (interregional travel): Social/recreational + school/church. Interregional travel belonging to this cluster is most likely to contain social/recreational activities.

Cluster 2 (interregional travel): Work-related. Cluster 2 contains interregional travel dedicated to work-related activities.

Cluster 3 (interregional travel): Other + social/recreational. Trip chains belonging to this cluster are for other-purpose activities and most likely to relate to social/recreational activities with a probability of 0.145.

Cluster 4 (interregional travel): Shopping/errands + social/recreational. Trip chains within this cluster are for shopping/errands activities. These trip chains contain social/recreational activities with a high probability of 0.267.

Figure 2 Average share of activity participation for short-distance daily travel by purpose. (Cluster size: Cluster 1: 29,040. Cluster 2: 45,431. Cluster 3: 62,817. Cluster 4: 24,968. Cluster 5: 46,581.)

Figure 3 Average share of activity duration for short-distance daily travel by purpose. (Cluster size: Cluster 1: 29,040. Cluster 2: 45,431. Cluster 3: 62,817. Cluster 4: 24,968. Cluster 5: 46,581.)

Figure 4 Average probability of activity participation for interregional travel by purpose. (Cluster size: Cluster 1: 19,367. Cluster 2: 11,724. Cluster 3: 6,396. Cluster 4: 3,463.)

Latent class model results

This section generates typologies of travelers and indicates how they combine daily travel and interregional travel. This model identifies typologies of travelers based on indicators that include the activity participation patterns and travel distances associated with daily travel and interregional travel (**Table 3**). The number of classes is selected based on comparing fit indices (CAIC) of LCA models with only indicators. As a result, the six-class model is selected with a relatively small CAIC (**Figure 5**). The six-class model is then extended by the inclusion of uncorrelated active covariates. Active covariates are predictors of class membership. The aggregated characteristics of inactive covariates are analyzed based on the mean values for each class. Classes are named according to the characteristics of indicators. Gender, employment status, vehicle ownership, age, and household income are primary distinguishing variables to predict class membership. Life cycle status, driver's license status, education status, and living environment are analyzed as inactive covariates as they do not have a strong relationship with classes. This section first describes latent classes based on indicators and covariates (**Table 4**). Then this section discusses the coefficient estimates of active covariates in the membership model (**Table 4**).

Table 3 Overview of the indicator variables in the model

Indicator variables		min	max	mean	std
Trip chains of Cluster 1 (daily travel)	0	0	1	0.815	0.388
	1	0	1	0.165	0.371
	>=2	0	1	0.020	0.139
Trip chains of Cluster 2 (daily travel)	0	0	1	0.676	0.468
	1	0	1	0.273	0.446
	>=2	0	1	0.051	0.220
Trip chains of Cluster 3 (daily travel)	0	0	1	0.584	0.493
	1	0	1	0.318	0.466
	>=2	0	1	0.098	0.297
Trip chains of Cluster 4 (daily travel)	0	0	1	0.846	0.361
	1	0	1	0.124	0.330
	>=2	0	1	0.030	0.170
Trip chains of Cluster 5 (daily travel)	0	0	1	0.629	0.483
	1	0	1	0.334	0.472
	>=2	0	1	0.037	0.188
Trip chains of Cluster 1 (interregional travel)	0	0	1	0.356	0.479
	1	0	1	0.491	0.500
	>=2	0	1	0.153	0.360
	0	0	1	0.799	0.401

Trip chains of Cluster 2 (interregional travel)	1	0	1	0.147	0.354
	>=2	0	1	0.054	0.225
Trip chains of Cluster 3 (interregional travel)	0	0	1	0.844	0.363
	1	0	1	0.090	0.286
	>=2	0	1	0.066	0.248
Trip chains of Cluster 4 (interregional travel)	0	0	1	0.875	0.331
	1	0	1	0.101	0.301
	>=2	0	1	0.024	0.153
Daily travel distance	<=10 miles	0	1	0.367	0.482
	10–30 miles	0	1	0.402	0.49
	30–100 miles	0	1	0.231	0.422
Interregional travel distance	100–200 miles	0	1	0.407	0.491
	200–400 miles	0	1	0.357	0.479
	400–600 miles	0	1	0.127	0.333
	600–1200 miles	0	1	0.108	0.311
Number of observations		**15,497**			

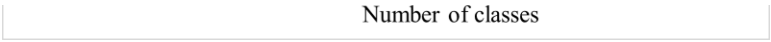

Figure 5 Model selection based on CAIC

Table 4 Variable mean and percentage for latent classes of travelers

Latent classes*	**Class 1**	**Class 2**	**Class 3**	**Class 4**	**Class 5**	**Class 6**
Class size	1771	3704	2525	3701	1981	1815
Proportion	11%	24%	16%	24%	13%	12%
Prediction of indicator variables						
Trip chains of Cluster 1 (daily travel):						
0	83.0%	83.1%	82.8%	71.0%	80.6%	97.7%
1	15.8%	15.2%	15.4%	25.7%	16.8%	2.3%
>=2	1.2%	1.7%	1.8%	3.2%	2.7%	0.1%
Mean	0.182	0.187	0.191	0.325	0.222	0.024
Trip chains of Cluster 2 (daily travel):						
0	61.8%	65.0%	66.0%	62.7%	67.2%	90.7%
1	34.3%	29.2%	28.1%	30.9%	26.8%	9.0%
>=2	3.9%	5.8%	5.9%	6.4%	6.0%	0.2%
Mean	0.421	0.412	0.402	0.447	0.391	0.095

Trip chains of Cluster 3 (daily travel):						
0	49.2%	56.0%	56.2%	56.0%	50.9%	88.0%
1	42.8%	33.1%	32.5%	33.1%	35.0%	11.5%
>=2	8.0%	10.9%	11.2%	10.9%	14.1%	0.5%
Mean	0.598	0.572	0.580	0.576	0.681	0.126
Trip chains of Cluster 4 (daily travel):						
0	81.0%	83.5%	82.6%	84.8%	82.1%	95.7%
1	16.0%	13.5%	14.2%	11.6%	13.8%	4.2%
>=2	2.9%	3.0%	3.2%	3.6%	4.1%	0.1%
Mean	0.221	0.201	0.215	0.200	0.230	0.044
Trip chains of Cluster 5 (daily travel):						
0	99.8%	58.5%	61.2%	75.6%	74.2%	0.0%
1	0.2%	37.3%	35.6%	20.5%	18.5%	97.4%
>=2	0.0%	4.2%	3.2%	3.9%	7.3%	2.6%
Mean	0.002	0.460	0.423	0.286	0.341	1.028
Trip chains of Cluster 1 (interregional travel):						
0	41.1%	31.3%	41.9%	0.0%	95.7%	37.4%
1	45.0%	52.8%	43.2%	77.5%	1.6%	47.4%
>=2	13.9%	16.0%	14.9%	22.5%	2.7%	15.2%
Mean	0.839	0.921	0.851	1.358	0.097	0.853
Trip chains of Cluster 2 (interregional travel):						
0	75.5%	80.0%	80.0%	94.5%	53.4%	83.1%
1	16.3%	15.8%	13.6%	4.5%	33.8%	12.6%
>=2	8.2%	4.2%	6.3%	1.0%	12.8%	4.4%
Mean	0.364	0.260	0.298	0.069	0.682	0.242
Trip chains of Cluster 3 (interregional travel):						
0	85.0%	82.8%	85.8%	96.8%	68.5%	77.2%
1	7.5%	10.5%	8.2%	2.1%	17.5%	13.6%
>=2	7.5%	6.7%	6.0%	1.1%	14.1%	9.3%
Mean	0.586	0.342	0.489	0.082	0.986	0.600
Trip chains of Cluster 4 (interregional travel):						
0	85.1%	91.4%	81.9%	97.2%	70.4%	88.7%

1	12.1%	7.3%	14.1%	2.2%	24.2%	8.9%
>=2	2.8%	1.3%	4.0%	0.6%	5.4%	2.4%
Mean	0.196	0.103	0.243	0.035	0.371	0.150
Daily travel distance:						
<=10 miles	0.0%	0.0%	0.0%	100.0%	100.0%	0.0%
10–30 miles	0.0%	100.0%	100.0%	0.0%	0.0%	0.0%
30–100 miles	100.0%	0.0%	0.0%	0.0%	0.0%	100.0%
Interregional travel distance:						
100–200 miles	43.0%	0.0%	100.0%	36.4%	48.7%	39.4%
200–400 miles	34.5%	59.4%	0.0%	38.7%	31.4%	36.7%
400–600 miles	12.1%	22.3%	0.0%	12.8%	10.3%	13.7%
600–1200 miles	10.4%	18.3%	0.0%	12.1%	9.5%	10.1%
Active Covariates						
Gender:						
Female	52.9%	49.5%	51.9%	55.3%	48.8%	40.1%
Male	47.1%	50.5%	48.1%	44.7%	51.2%	59.9%
Employment status:						
Unemployed	48.6%	31.3%	34.6%	52.2%	37.5%	0.2%
Employed	51.4%	68.7%	65.4%	47.8%	62.5%	99.8%
Vehicles per person in household	0.938	0.934	0.919	0.793	0.900	1.022
Age/100	0.416	0.417	0.420	0.372	0.435	0.422
ln(Adjusted income)/10	1.041	1.054	1.043	1.042	1.039	1.063
Inactive Covariates						
Life cycle status:						
Not have children	49.4%	48.1%	46.7%	40.1%	48.8%	49.6%
Have children	50.6%	51.9%	53.3%	59.9%	51.2%	50.4%
Driver's license status:						
Not have driver license	17.1%	12.1%	13.5%	29.0%	15.3%	0.7%
Driver's license status	82.9%	87.9%	86.5%	71.0%	84.7%	99.3%
Education status:						
Education level 1: <=high school or GED (General Educational Development)	50.0%	38.7%	45.6%	53.4%	42.4%	28.2%
Education level 2: some college or associates degree	22.0%	24.3%	25.8%	21.0%	25.0%	31.7%

Education level 3: bachelor's degree	16.0%	20.1%	15.8%	14.2%	18.0%	23.9%
Education level 4: graduate degree or professional degree	12.0%	16.9%	12.8%	11.3%	14.5%	16.3%
Live in MSA status:						
Live in an MSA with population of less than 250,000	6.9%	10.9%	9.9%	8.1%	9.8%	7.7%
Live in an MSA with population of 250,000-499,999	8.4%	9.0%	9.1%	9.5%	7.6%	7.8%
Live in an MSA with population of 500,000-999,999	6.0%	9.4%	7.1%	7.8%	6.3%	6.4%
Live in an MSA with population of 1,000,000-2,999,999	17.3%	23.6%	19.2%	20.8%	16.4%	20.2%
Live in an MSA with population of 3,000,000+	23.8%	26.1%	24.9%	32.6%	23.1%	32.5%
Not live in MSA	37.5%	21.0%	29.7%	21.2%	36.8%	25.5%
Live in urban area status:						
Not live in urban area	47.0%	25.2%	33.7%	15.9%	23.1%	34.3%
Live in urban area	53.0%	74.8%	66.3%	84.1%	76.9%	65.7%
Prediction of latent class membership						
Values	**Class 1**	**Class 2**	**Class 3**	**Class 4**	**Class 5**	\
(Intercept)	8.453***	6.473***	8.565***	9.462***	8.876***	\
Age/100	0.555*	0.633**	0.703**	-0.043	1.226***	\
ln(Adjusted income)/10	-2.999***	-0.764	-3.028***	-2.555***	-3.604***	\
Male (ref: female)	-0.337***	-0.265***	-0.342***	-0.420***	-0.204**	\
Employed (ref: unemployed)	-5.977***	-5.288***	-5.380***	-6.042***	-5.493***	\
Vehicles per person in household	-0.036	-0.152**	-0.185**	-0.586***	-0.301***	\

Latent classes of travelers

Class 1: Leisure travelers

Class 1 is the smallest class (11%). People from this class mainly make daily travel for leisure from cluster 2 (0.421) and cluster 3 (0.598). These two clusters present higher frequencies compared to other clusters. They make more interregional travel associated with activities for social/recreational (cluster 1) and other purposes (cluster 3). In addition, the class is characterized by a long daily travel distance (30–100 miles) and a relatively short interregional travel distance (100–400 miles).

Class 2: Daily leisure and work + interregional leisure travelers (200–1200 miles)

Class 2 is the largest class (24%). Individuals in this class report most daily travel for leisure and work from clusters 2, 3, and 5. They make most social/recreational interregional travel from cluster 1. Additionally, the class features daily travel distance and interregional travel distance in the middle range of 10–30 miles and 200–1200 miles respectively.

Class 3: Daily leisure and work + interregional leisure travelers (100–200 miles)

Class 3 contains travelers who make daily travel mainly for leisure from cluster 2 and cluster 3. They also make more interregional travel for social/recreational activities from cluster 1. All daily travel belonging to this class has travel distance in the range of 10–30 miles, and all interregional travel distance is in the range of 100–200 miles.

Class 4: School/church + leisure travelers

Class 4 present to be the second largest class (24%), with travelers making daily travel for school/church and leisure from cluster 1, 2, and 3. Interregional travel they make is largely from cluster 1 for social/recreational. The daily travel distance is all less than 10 miles, and the interregional travel distance is almost less than 400 miles.

Class 5: Leisure and work travelers

Class 5 comprises travelers who mainly travel daily from cluster 3 for shopping/errands. The interregional travel is for work-related activities from cluster 2 and other purpose activities from cluster 3. The daily travel distance is less than 10 miles, and the interregional travel distance is largely less than 400 miles.

Class 6: Daily work and shopping/errands + interregional leisure travelers

Class 6 contains travelers who perform most daily travel from cluster 5, which is mainly associated with work-related activities and combined with shopping/errands activities. They make interregional travel mostly from cluster 1 for social/recreational activities. The daily travel distance is in the range of 30–100 miles, and interregional travel distance largely has the distance range of 100–400 miles.

Household characteristics present mixed results for classes. Profiles for these latent classes are created based on the summary statistics obtained using posterior class membership. *Leisure travelers* (Class 1) have a small share of males (47.1%) and a relatively large share of unemployed people (48.6%) compared to other classes. About half of the people within this class have an education lower than high school or GED. A little more than half of people from this class live in urban areas. *Daily leisure and work + interregional leisure travelers (200–1200 miles)* (Class 2) contain about half females and half males. The share of unemployed people is relatively small (31.3%). This class contains the largest share of "graduate degree or professional degree" (16.9%) compared with other classes. *Daily leisure and work + interregional leisure travelers (100–200 miles)* (Class 3) are mainly made up of individuals with education level 1 and level 2. *School/church + leisure travelers* (Class 4) have the largest share of females (55.3%) compared with other classes. Many of its members are employed (52.2%). It has the lowest average vehicle ownership in households (0.793) and youngest travelers with an average age of 37.2. Regarding the inactive covariates, the class has the highest share of households with children (59.9%). This class contains the vast majority of people with no driver's license (29%) and education lower than high school or GED (53.4%). Most people belonging to this class live in an MSA with a population of more than 1,000,000 people and live in urban areas. *Leisure and work travelers* (Class 5) have the oldest travelers (43.5) and the lowest income compared with other classes. *Daily work and shopping/errands + interregional leisure travelers* (Class 6) have the highest proportion of males (59.9%) compared with other classes. Almost all individuals belonging to *Daily work and shopping/errands + interregional leisure travelers* (Class 6) are employed. They have the most vehicles per person on average and have the highest income. Unsurprisingly, this class has the largest proportion of drivers. A relatively large share of individuals from this class lives in MSAs with a population of more than 3,000,000.

Class membership model

The portion of latent class membership prediction in **Table 4** displays coefficients of active covariates in the membership model, and Class 6 is the reference class. The elderly are more inclined to belong to *Leisure and work travelers* (Class 5), whereas they are less inclined to be *School/church + leisure travelers* (Class 4). Individuals with high household income are less likely to be *Daily leisure and work + interregional leisure travelers (100–200 miles)* (Class 3) or *Leisure and work travelers* (Class 5) compared with other classes. Being male is negatively associated with belonging to Class 1–5 and the most unlikely to belong to *School/church + leisure travelers* (Class 4). Being employed has a negative association with being in Class 1–5. Employed individuals have a lower potential to be affiliated with *Leisure travelers* (Class 1) or *School/church + leisure travelers* (Class 4). More vehicles per person in a household decrease one's probability of belonging to Class 2–5 and lead to the lowest likelihood of being *School/church + leisure travelers* (Class 4).

DISCUSSIONS AND CONCLUSIONS

This study extends the ongoing research on the integration of daily travel and interregional travel from two aspects.

First, this study explores the complexity of daily and interregional trip chains using descriptive analysis and cluster analysis, which overcome the limitations of predefined complexity typologies. By presenting the composition of activity purposes within daily travel and interregional travel trip chains, this study reveals the discrepancies between daily travel and interregional travel regarding travel purpose complexity. Interregional travel has a larger portion for single-purpose activity than daily travel, among which daily travel largely contains leisure activities, including shopping/errands and social/recreational, and interregional travel is largely associated with social/recreational and work-related activities. Multiple-purpose trip chains take a nonnegligible portion for daily travel and interregional travel. Within multiple-purpose travel, a large portion of trip chains is for leisure activities, including shopping/errands and social/recreational. It should be noted that for work-related travel, interregional trip chains mainly connect to social/recreational activities, and daily trip chains largely integrate shopping/errands activities. The travel purpose complexity demonstrates that people tend to incorporate non-work activities into work-related travel. The common travel market segmentation between work and non-work travel and pure focus on work travel is insufficient (*38*).

The cluster analysis produces clusters to represent travel purpose complexity based on the activity participation patterns for daily travel and interregional travel, which answer the first research question regarding the purpose complexity of trip chains. There are five daily travel clusters identified, including *School/church + shopping/errands*, *Social/recreational + shopping/errands*, *Shopping/errands*, *Other + shopping/errands*, and *Work-related + shopping/errands*, and four interregional travel clusters, including *Social/recreational + school/church*, *Work-related*, *Other + social/recreational*, and *Shopping/errands + social/recreational*. The cluster analysis outperforms predefined travel purposes in two aspects. First, the cluster analysis functions as a data-driven approach that allows for reducing bias. Second, the cluster analysis enables us to consider the continuous activity participation factors, including average shares of activity participation, average shares of activity duration, and average probabilities of activity participation.

The second aspect of this study's contribution lies in exploring traveler latent classes based on their participation in daily and interregional travel. The results answer the second research question describing how people arrange activities associated with daily travel and interregional travel. Class 1 contains travelers who make daily and interregional travel for leisure purposes. Class 2 is composed of travelers who do daily leisure and work travel and interregional leisure travel with a distance of 200–1200 miles. Travelers from Class 3 tend to make daily leisure and work travel and interregional leisure travel with a distance of 100–200 miles. Class 4 contains travelers who make daily and interregional travel for school/church or leisure purposes. Travelers from Class 5 make daily and interregional travel for leisure and work purposes. Class 6 is made up of travelers who tend to do daily work and shopping/errands travel

and interregional leisure travel. Household characteristics are mixed across classes. Class 1 features with youngest travelers, indicating young people tend to make daily and interregional travel for leisure purposes. People with old age are the most likely to be in Class 5, whereas people with high income are the least likely to belong to Class 5. It suggests that high-income people are least inclined to combine leisure and work-related activities within trip chains. Class 6 comprises a large portion of males across the classes. Class 6 is almost all composed of employed travelers, and being employed has negative effects of belonging to other classes. Similarly, vehicle ownership has the largest rate for people in Class 6. This indicates that travelers who make daily travel for work and shopping/errands, and interregional leisure travel are almost employed and have high vehicle ownership. Inactive variables that do not have impacts on the class membership, including life cycle status, driver's license, education status, and living environment, are analyzed based on the mean values for each class (*39*).

To conclude, daily travel and interregional travel are complex regarding travel purposes, and people organize activities associated with daily travel and interregional travel in different ways. This study supports the development of an activity-based travel demand model that integrates daily travel and interregional travel.

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