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Sustainable commute in a car-dominant city: Factors affecting alternative mode choices among university students

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ABSTRACT

This paper studies university students' commute and housing behaviors using samples from Los Angeles, a place notorious for car dependence and dominance. It finds that being embedded in this place does not make university students drive alone more than their peers in other places. Being multimodal and having a discounted transit pass increase the odds of alternative modes while holding a parking permit reduces the odds of these modes. Commute distance is positively related to carpool and telecommuting. Gender, status (undergraduate vs. gradate) and age are significantly correlated to biking, walking or public transit. Students living alone are more likely to commute by driving alone than other students. Having friends and classmates living nearby increases the odds of taking public transit. Due to data constraints, this study cannot prove whether there is any correlation between information contagion and the effects of living alone and having friends and classmates living nearby on alternative mode choice. But it proposes that the issue be worthwhile of further investigations. Base on the above, the paper recommends a comprehensive travel demand management program, utilization of information contagion effects of students and promotion of multimodal commute to better promote alternative mode of commute among university students.

1. Introduction

One can never exaggerate the role of university education and experience to personal growth, social progress and sustainable development of the world. From the personal perspective, university education and experience facilitate one's growth as a cultivated, responsible, sensible and skilled citizen. From the societal perspective, university education and experience enable a large-scale of conveyance and reproduction of knowledge, ideas, skills, customs and behavioral patterns. From the perspective of promoting sustainable development in general and sustainable transportation in particular, university education and experience could reinforce or reshape university students' behaviors and awareness and produce good exemplars for the society at large. At the individual level, what one did or believed as a university student also has profound effects on what he does as he grows (Carlos, 2003). Some of today's students would also eventually progress to important roles such as CEOs, CFOs, managers, mayors, professors and congressmen which might help trigger positive changes in our society, awareness and behaviors.

In 2008, there were over 13 million full-time college students and nearly six million part-time college students in the United States (US Census Bureau, 2008). Both student groups combined accounted for over 6% of the US population. Given the roles of university education and experience highlighted above and the absolute number of college students and potential number of people that they interact with and influence, promoting/studying sustainability in general and encouraging

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sustainable travel behaviors at universities in particular are not a trivial issue. First, promoting sustainability would not only be today's universities' social responsibility but also be in their self-interest (Orr, 1992). Second, universities are always some of the largest employers in cities or counties where they reside and their sustainability efforts would help establish exemplars for other employers and even for the society at large (Carlos, 2003); Third, sustainability efforts or experiments at universities would deepen our understanding of, and directly contribute to a specific place's sustainability. Fourth, biking and walking as sustainable mode choices might even reduce obesity and illness that we have increasingly observed in the society (Lin and Chang, 2010; McDonald, 2005, 2007; Lorenc et al., 2008; Pooley et al., 2005; Sirard and Slater, 2008). Last but not least, even we simply want to develop better travel demand models in places where the university is a dominant trip generator, we need to better study travel patterns of university students too (Khattak et al., 2011; Eom et al., 2009).

To the author's knowledge, few existing studies have examined the relationship between mode choice of university student commuters and its influencing factors. One most relevant study focused on mode choice before and after a free transit pass program was implemented (Boyd et al., 2003). The other two relevant studies looked at travel patterns of university population as whole rather than those of university students alone (Shannon et al., 2006; Rodriguez and Joo, 2004). Since the data of this study are about student commuters from the same university, this study controls the impacts of factors such as transit costs, topography, climate, university profile and urban form on mode choice. These factors were not controlled in relevant existing studies on university students' travel such as Khattak et al. (2011) and Carlos (2003). Also, unlike existing studies adopting the perspective of developing activity-based travel demand models (Eom et al., 2009; Khattak et al., 2011), this study specifically examines alternative modes such as biking, walking, carpool, public transit and telecommuting and their influencing factors. Given the above, this study supplements existing studies on sustainable transportation at universities in general and sustainable mode choice of university students in the US context in particular. Car dependence and dominance characterize this context.

Specifically, based on travel and housing survey data of university students in Los Angeles, a place probably best signifies the extreme car dependence and dominance in the world, this paper/study examines the following questions:

- Whether being embedded in Los Angeles would make university students drive alone more than their peers in other places?
- If the university students' commute mode is biking, walking, public transit, carpool or telecommuting, which factors have the most significant impacts on these mode choices, respectively?
- Are the above factors influencing mode choices differ between the university students in Los Angeles and their counterparts elsewhere?
- Overall policy and practical implications from answers to the aforementioned questions.

The motivations underlying the above questions are two folds. First, whether and how much university students can enhance the world's sustainability is subject to many factors, in particular, the overall social structure where they are embedded and the effects of positive information contagion on the society they generate or contribute to. Granovetter (1985) uses "embeddedness" to describe the situation that people guide their choices based on past interactions with people and continue to deal with those they trust (Granovetter, 1985). Since Granovetter, many other scholars have examined the effects of embeddedness on people choices or behaviors (e.g., Radil et al., 2010; Rivera et al., 2010). But "embeddedness" has rarely been used by transportation scholars to study people's mode choice. Little is known about how embeddedness affects university students' mode choice. In this study, university students in Los Angeles are thought to be deeply embedded in a culture, social network and place characterized by car dependence. This embeddedness partially explains why some of these students simply drive alone to get around. On the other hand, others still manage to avoid driving alone partially because of information contagion, which Arthur and Lane (1993) use to depict the phenomenon that people making buying decisions based on publicly available information as well as private information from prior buyers. But little has been done on how information contagion influences mode choices of general population as well as university students. Particularly, despite that existing studies have examined the impacts of factors such as commute distance, transit proximity,[1] transit fare level and parking cost on university students' mode choice (see Section 2 below), few have explored whether living with or in proximity to other students would influence a student's commute mode choice such as biking, walking and transit. In this study, living with or in proximity to other students was regarded as a factor increasing the effects of information contagion or interpersonal networks, through which "small-scale interaction becomes translated into large-scale patterns" (Granovetter, 1973). Also, given the fact that Los Angeles has been a place notorious for its entrenched car dependence, its successful practices and experiences in promoting alternative mode choices should provide other places with useful references and some confidence in their respective promotion efforts.

This paper is organized as follows. Next section (Section 2) introduces relevant literature in place. Sections 3 and 4 describe the study subjects and data sources. Sections 5–7 present empirical results and discuss how they are related to existing studies, if applicable. Section 8 concludes and discusses future directions of this study.

[1] Transit proximity this study and most existing studies means living within a walking distance to at least one bus line. Transit includes bus (public transportation), metro (subways) and campus shuttle in this study.

2. Relevant research

2.1. Factors influencing mode choice of the general population

A desktop literature search using the Web of Science, Engineering Village and TRID databases uncovers six groups of factors influencing mode choice of the general population:

- Group 1: Physical environment and urban form factors such as population density, land use mixture, topography, availability of infrastructure, and multimodal network's connectivity.
- Group 2: Mode-specific factors such as availability, access, convenience, comfort, privacy, freedom, safety, travel time and cost.
- Group 3: Trip-makers' personal attributes such as occupation, marriage status, gender, age, income, daycare responsibilities, car ownership and possession of a driver's license.
- Group 4: Trip characteristics such as time of travel, trip purpose, trip distance, trip origin and destination.
- Group 5: Presence of Travel Demand Management (TDM) measures such as parking cost or restriction information campaigns against car usage and transit pass subsidy.
- Group 6: Psychological factors such as habit, attitude, concerns over health and the environment, familiarity with alternative modes to driving and unconscious attachment to car usage. In the case of this study, embeddedness and information contagion are regarded as two Group 6 factors.

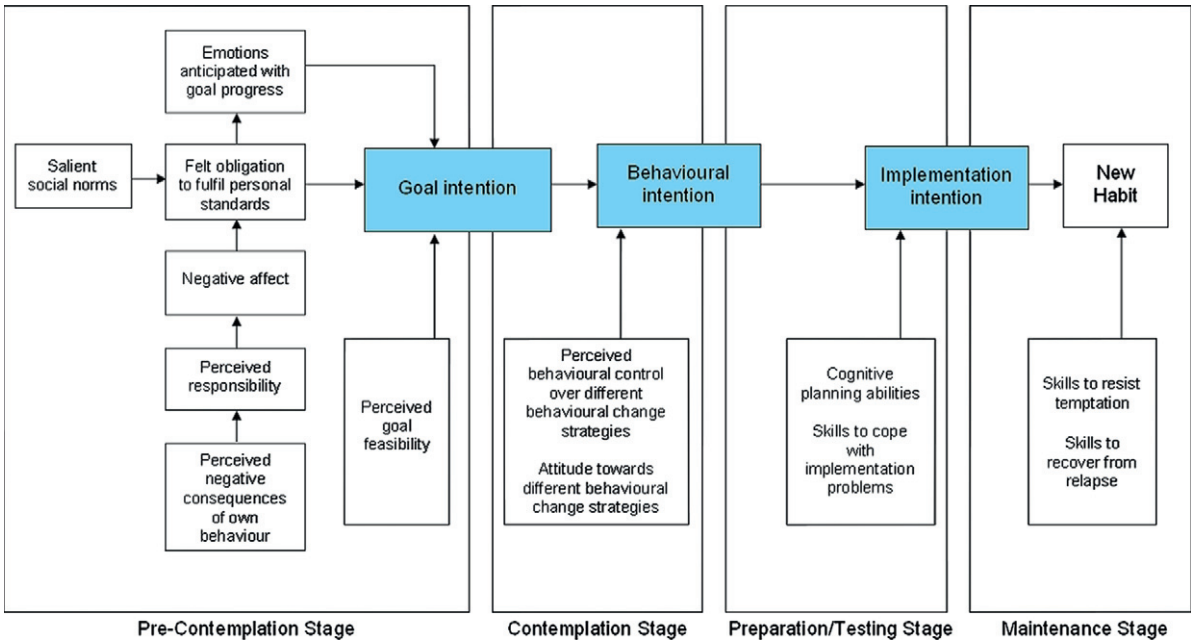
The above factors have not been given equal attention to in existing literature identified. The Group 1, for instance, has received probably the most attention. Relevant studies have been so prolific that there have been at least four comprehensive reviews of the published literature (Badoe and Miller, 2000; Crane, 2000; Ewing and Cervero, 2001, 2010). The latest review indicates that most Group 1 factors alone are not a significant predictor of mode choice. Several Group 1 factors together are a more significant predictor of mode choice, for instance, walking is most strongly related to measures of land use diversity, intersection density, and the number of destinations within walking distance. Bus and train uses are equally related to service proximity and street network design variables, with land use diversity a secondary factor.

Despite its popularity in the academia, Group 1 is not as a popular predictor as Groups 2–4 in conventional mode choice models at transportation planning entities. In the latest mode choice model of Southern California Association of Governments (SCAGs), for instance, the predictors are: trip purpose, travel time (including in-vehicle, transfer and out-of-vehicle times), distance (for biking and walking modes), trip destination (CBD vs. non-CBD), time of day and vehicle rate per household member (Southern California Association of Governments, 2008). Similar to SCAG, the New York Metropolitan Transportation Council (NYMTC) activity-based model uses variables such as auto ownership, trip makers' personal attributes and destination characteristics or composite variables based on them to predict mode choice (Vovsha and Chiao, 2008). Both SCAG and NYMTC are of the most technologically sophisticated metropolitan planning organizations (MPOs) in the US. Their choice of predictors mentioned above reflects that Group 1, as compared to Groups 2–4, is only regarded by leading MPOs as a secondary factor influencing mode choice.

Despite their impacts on mode choice cannot be easily singled out from other factors', TDM measures have been adopted by many employers or been advocated by several high-profile entities (Federal Transit Administration et al., 2003; Victoria Transport Policy Institute, 2011; Zhou et al., 2012). A survey of 58 TDM projects in southern California concludes that TDM measures are very effective in changing commuters' modes or residential location (Federal Transit Administration et al., 2003). But comparisons of different employee commuter groups shows that a better jobs/housing balance is accompanied by higher income, as is likelihood to use alternative modes subsidized by TDM programs, which are costly to implemented (Zhou et al., 2012). Using TDM programs to shift people from driving to alternative modes is not only costly but also involves changes at a larger scale that recently caused them to drive and "[t]his is quite apart from the changes in behavior caused by becoming a car owner for the first time" (Goodwin, 1977). Similar phenomena like the aforementioned gave rise to the study of Group 6's impacts on mode choice, which is based on Ajzen (1991), Schwartz (1977) Schwartz and Howard (1981).

Ajzen (1991) develops the theory of planned behavior (TPB). TPB's key concepts are attitudes, social norms and perceived behavioral control, which fall into Group 6 factors mentioned above. Schwartz (1977) and Schwartz and Howard (1981) advance the norm-activation model (NAM). NAM assumes that the driving force of behavior is a feeling of moral obligation. Both NAM and TPB proved useful in explaining travel mode choice (e.g., Bamberg and Schmidt, 1998; Klöckner and Blöbaum, 2010; Klöckner and Friedrichsmeier, 2011; Klöckner and Matthies, 2004). Based on NAM and TPB, Klöckner and Blöbaum (2010) and Klöckner and Friedrichsmeier (2011) argue that in addition to Groups 2–3 factors such as car availability, trip purpose and travel cost, Group 6 factors such as intentions, environmental belief and habits also have a significant impact on mode choice. Thus, to shift drivers to other alternative modes, public policy strategies should focus on individuals' environmental beliefs and situations such as discounted public transportation passes (Collins, 2005). This is generally consistent with the MaxSem model of travel mode change developed by Carreno and Rye (2009), which emphasizes informing travelers of the negative consequences of their behaviors as the starting point of changing their mode choice (see Fig. 1).

When assessing the impacts of Groups 1–6 factors on mode choice, only a few existing studies focus on university students (Boyd et al., 2003; Collins and Chambers, 2005; Bamberg et al., 2003; Klöckner and Friedrichsmeier, 2011; Rose, 2008).



Source: Adapted from Carreno and Rye (2009).

Fig. 1. MaxSem model of travel mode change. *Source*: Adapted from Carreno and Rye (2009).

This is also reflected in a recent comprehensive review of mode-choice literature (Gärling and Fujii, 2009). Generally speaking, university students, however, are different from the general population, particularly the employees, at least in the following dimensions:

- They have some control over their course schedule and time of commute and can often avoid two peak hours typically faced by most employees. Khattak et al. (2011) and Santos et al. (2011), for instance, show that university students' single peak hour of commute was around midday while employees' two peak hours were around 7am and 5 pm, respectively.
- Most university students are unmarried[2] and/or have no kids and thus do not have any daycare responsibilities to constrain their transportation and housing choices.
- Compared to workers, university students are lower in car ownership or access. In four universities in Virginia, for instance, the car ownership per student ranges from 0.72 to 0.9 (Khattak et al., 2011) while the comparable car ownership per worker in the US is 1.39 (Santos et al., 2011).
- Due to facts such as lower (or even no) income and younger age, university students are more likely to use public transportation, bike or walk than the general population. Bus Partnership Forum in London (2003), for instance, finds that many local students are "captives" of the bus.
- University students overall have more positive attitude towards TDM measures than the general population (Toor and Havlick, 2004).

2.2. Factors influencing mode choice of university students

Existing studies on factors influencing mode choice of university students focus on Groups 4–6. But Group 6 has only been given attention recently. Little has been done on how embeddedness and information contagion would affect mode choice. Only a few articles indirectly touch on embeddedness and information contagion in the Australian and European contexts. Other articles have focused on Groups 4 and 5's impacts on mode choice.

2.2.1. Australian studies

Based on a sample of 205 Australian university students, Collins and Chambers (2005) find that mode-specific cost, time (distance), and access (especially transit proximity) and environmental awareness jointly influence mode choice or probable shift to public transportation from driving. The above results; however, are based on a stated preference survey rather than observed mode choice before and after actual policy interventions were introduced. Therefore, one has to be a little cautious here.

[2] In Brigham Young University, Utah, a state known for young marriage age, for instance, there are always at least 71% of students are single between 1988 and 2011, see: http://yfacts.byu.edu/viewarticle.aspx?id=188.

Also in Australia, several other authors examine the mode choice of students and staff combined, finding that perceived and actual travel time by bus and bike had the greatest impacts on transit and biking rates (Shannon et al., 2006). Their recommended strategies to promote sustainable mode choices included: subsidizing transit passes, introducing student housing on or near campus; increasing cost of parking, improving bus services and building bike networks.

Rose (2008) describes the experience of the TravelSmart program at Monash University in Melbourne, Australia. TravelSmart focuses on first-year students and provided person-to-person assistance to these students once they decided to attend Monash. The assistance ensures that these students obtained complete, timely and accurate information about alternative modes such as public transit and carpool. Self-reported impacts showed that TravelSmart significantly increases public transit rates among Monash's students.

Based on another 186 university student samples in Australia, Kerr et al. (2010) show that behavioral intention to travel by car is the strongest psychological factor that contributes to car dependence. This intention is not necessarily a result of habitual car usage. They thus propose that efforts to reduce car dependence should focus on perception of private car and high-level of acceptability of such perception.

2.2.2. European studies

Klöckner and Friedrichsmeier (2011) argue that mode choice was jointly determined by situational factors and psychological factors. Situational factors include availability of infrastructure by mode, transit accessibility, trip characteristics and cost (e.g., Ewing et al., 2004) while psychological factors encompass individuals' intentions, belief, norms and attributes (e.g., Collins and Chambers, 2005). They propose that a two-level structural equation model be more appropriate when studying the impacts of different situational and psychological factors on mode choice in general and car use in particular. They use the survey responses from 560 German university students to develop a model to support their argument. Model results produce evidences in support of the argument.

Other authors have identified that in addition to benefits such as convenience and autonomy provided by the car, many young people in the UK commute by driving or are planning to do so once they have enough money because of affective motivation and the symbolic function of the car (Maxwell, 2001; Stradling, 2002, 2011).

2.2.3. Other studies

In a special program where university students are provided free services on selected bus lines in Los Angeles, Boyd et al. (2003) find that after the free bus services are introduced the rate of students using the bus increases at the expense of decreased driving, walking and biking rates. The bus rate of students living within a half mile of a direct bus line to campus sees the most significant growth. Since other factors such as built environment, socio-psychology and economic status of students remain relatively stable in the case, the above facts indicate that free bus services have a positive impact on university students' bus usage. But probably due to data constraints, the authors do not examine how many students moved into the catchment area of the free bus services and/or changed their mode choice because of free transit services. In other words, we are not clear whether some students self-selected into the catchment area and how self-selection and transit proximity jointly influence usage of transit. This study will address these issues by asking students why they chose their current residences and will study how the answers are related to students' mode choice.

In another bus-related program for university students, the results show that a prepaid bus-ticket increases college students' bus trips as well students' positive attitude toward bus services (Bamberg et al., 2003). But students' experience of, and attitude towards bus contribute to the prediction of later mode choice only if circumstances remain relatively stable. In other words, a stand-alone policy intervention does not have long-term or stable impacts on mode choice. Linking this to the above free bus program, the increased bus usage described by Bamberg et al. could be a temporary phenomenon.

As whole, the above literature review indicates:

(a) Little has been done on university students' mode choice and its influencing factors, particularly in the US context.
(b) Despite some relevant studies of the impacts of embeddedness and information contagion on university students' mode choice were in existence, still little is known.
(c) Given the above situations, few policy recommendations based on empirical results are in place about promoting sustainable mode choices among university students.

3. The study subjects

The sample of this study is from the active student population (N = 36,503) of the University of California, Los Angeles (UCLA) as of May 2010. UCLA is located in a community called Westwood in the west of Los Angeles. Los Angeles enjoys a subtropical-Mediterranean climate, which is almost perfect for users of alternative commute modes such as biking and walking. Los Angeles rarely becomes too hot or too cold, enjoys 300 plus sunny days for most years with a record and has an average daily temperature of 19 °C.[3] Most Los Angeles and Westwood built-up areas are largely on moderate terrains, providing a friendly physical environment for pedestrians and cyclists. Fourteen bus lines by local transit companies served

[3] "Los Angeles Climate Guide". weather2travel.com. Retrieved October 5, 2011.

UCLA in 2010. These lines directly link UCLA to its neighboring cities as well as popular places among students and local residents such as LAX, West Hollywood, Beverly Hills, downtown Los Angles, Santa Monica and Culver City. For full-time students riding a bus to school, UCLA has provided 50% subsidy of the fare cost since 2003. On its main campus or adjacent area to the southwest, there is university-owned housing available to UCLA undergraduate and graduate students. As of 2010, the above UCLA housing accommodated about 10,000 students. UCLA used to be a commuter campus for decades but has been in a transition to a resident campus since it built more and more on-campus housing in past two decades. In addition to the above housing, on-campus housing that can accommodate more 3000 students is also being built at UCLA and is expected to welcome residents in 2013.

Given the above, a study of UCLA students' mode choice would be of interest to audiences like: (a) campus planners or policy analysts who want to better promote sustainable transportation among students in places where cars dominate; (b) travel demand program coordinators at the employer, city or county levels; (c) environmental advocates and university administrators who favor alternative modes of commute in a car-dominant context; (d) professionals or researchers who work on active transportation planning and policy.

4. Data sources and variables

The data for this study are from an on-line travel survey of active students at UCLA between May 2010 and June 2010. Of the active students, about 10% (3429) were randomly selected to receive the survey via Email. At UCLA, all active students have to supply the university with a valid email address to receive important information and documents such as emergency evacuation notice, classroom change notice, and tax-return form. The university then stores the addresses in a student database. Student email addresses in this database were used to randomly select the sample. It is believed that such a sampling process shall not produce any serious bias. Like other students surveys, this survey offered cash awards to a small number of respondents as incentives to increase response rate. Each award is a $75 prepaid credit card that is widely accepted and five winners were randomly chosen right after a publicized deadline for returning the completed survey. By the deadline, the survey hit a response rate of 22% (769/3429). Table 1 provides a comparison of the survey respondents and the UCLA student population. Based on Table 1, females and graduate students are a little overrepresented. But given that the biggest overrepresentation margin is about 20%, the respondents are still a reasonably unbiased sample of the population. A Chi-square test was further used to determine whether there was a difference in the percentage distribution of the survey responses and the population. The result reveals an insignificant difference, $X^2 = 1.45$ ($df = 5$, $N = 300$), $p = 0.08$. This confirms that the respondents reasonably well represent the student population.

After error-checking, cleaning and clearing the data, there are 508 responses that can be used for most of the questions addressed in this study.

The survey has two different sets of questions, depending on respondent's answer to the opening question. The question asks whether students live on- or off-campus. For off-campus respondents, they are directed to 10 questions about their commute patterns and housing choice. This study focuses on off-campus students only. For the on-campus, since their housing choices are known, they only answered five questions about their trips to class or to off-campus destinations. The nine questions of relevance to this study that the off-campus responded to are:

1. Primary mode of travel from home to UCLA on each weekday during May 10 and 14 of 2010.
2. Secondary mode, if applicable during the week.
3. Door-to-door travel time from home to UCLA by primary mode.
4. Zipcode of residence (also for verification purposes—past experience indicates that some students supplied their parents' address to the university while they actually lived in another address to ensure that they always receive important mails from UCLA) and the street intersection near one's residence.
5. Where to park if they drive to campus.
6. Time of travel from home to campus.
7. Primary reason that they chose current residence.
8. Residence type.
9. If they have multiple residences while at UCLA, whether they changed primary mode choice after moving at least once.

Table 1
Comparison of the respondent and population.

	Respondents ($n = 769$)		Population[a] ($n = 36,503$)	
	N	%	*N*	%
Living off-campus	555	72	25,870	70
Living on-campus	214	28	10,633	30
Male	307	40	17,050	46
Female	462	60	19,453	54
Undergraduate	250	45	24,176	66
Graduate	305	55	12,327	34

[a] Provided by UCLA office of analysis and information management.

The socio-economic characteristics of the respondents were anonymously retrieved by using respondents' email addresses as the key to link survey responses to the UCLA's student database, which contains student information such as gender, program, age, race, and home address. Following the IRB rules at UCLA, researchers can request certain information that does not disclose a particular student's identity. Following these rules, the author obtained additional nameless personal information about the respondents/students for this study. Table 2 summarizes the variables used in this study that are compiled from the above-mentioned survey and database.

5. Descriptive analysis

Based on Table 2 and valid responses of the survey, one can identify the following travel behavioral and housing characteristics of the students:

5.1. Mode choice

Like their counterparts mentioned in other studies (Khattak et al., 2011; Eom et al., 2009), the students living off campus are much "greener" commuters than the comparable general population—the UCLA employee commuters: as much as 56% of them use alternative modes such as biking, walking, or public transportation. For the latter group, only 25% of them do so (UCLA Transportation, 2010). Compared to their counterparts at five different universities in North Carolina and Virginia (Khattak et al., 2011; Eom et al., 2009), the UCLA students' alternative mode rate is not bad. It is only smaller than the rate at the University of Virginia, which is a large university in a college town. This indicates that embedded in Los Angles does not increase the driving-alone rate of the UCLA students.

5.2. Multimodal behavior

About half of the students are multimodal: 51% of them report more than one primary commute mode for different weekdays. Similar multimodal behaviors of their counterparts are not presented in any existing publications reviewed. Thus, one cannot be sure if the multimodal rate of the students is significantly higher than that of the general student population. But the above indicates that promoting multimodal behaviors among university is quite feasible.

5.3. Travel time

Regardless of time of commute, 73% of the students have a door-to-door commute time that is less than 60 min. Of these students, 96% of them have a time that is between 10 and 60 min. The percentage of the students with an extreme short trip that is shorter than 10 min is comparatively small. Only 2.7% of the students are so lucky. There are 21.4% of the students do have to spend more than 60 min on commuting. On the one hand this percentage indicates that some of the students have to suffer arduous commute; on the other hand, it shows the UCLA's hinterland or service area is quite large.

5.4. Parking

There are 33% of the respondents primarily drive alone to campus. This is consistent with the share of the responding students who have a permits parking for an on-campus lot at UCLA, which is 34%. But there are 54% of the respondents once parked on or around the campus. The difference between the two indicates that some students are de facto multimodal.

5.5. Time of travel

Unlike students who are younger and whose schedules are tied to their parents', most of university students commute in off-peak hours. The survey responses indicate that as many as 67% of the students travel in off-peak hours. This plus the fact that 3% of the students telecommute indicate that university students do not contribute as much to traffic congestion as younger students, a problem identified by Pooley et al. (2005) and Rhoulac (2005). In another study, Eom et al. (2009) also find most university students commute during off-peak hours. Based on the above, on the one hand, university students do not contribute as much to peak-hour traffic congestion as other younger students; on the other hand, it shows that university students do differ from the general population in time of travel.

5.6. Residence choice

Rent affordability, proximity to campus and community amenities are the top three factors that have the greatest influence on the students' residence choice. These three factors jointly explain why 75% of the students' chose their current residence. Only 6% of students chose their current residence primarily because of transit proximity. This might simply reflect the fact that most of the students living off-campus have access to a vehicle—as highlighted above, 54% of them once parked on or around the campus. Also, it is likely that many of them have a rather strong behavioral intention to travel by car in the

Table 2
Variables used in the study.

Variables	Description/notes	Summary statistics
Dependent variables		Share (%)
Solo driving[a]	Primary mode is driving alone and motorcycling alone	32.7
Transit	Primary mode is public transit, including campus shuttle	30.9
Carpool	Primary mode is carpooling	8.5
Biking or walking	Primary mode is biking or walking	24.8
Telecommuting	Do not commute during the five survey weekdays (Treated as telecommuting)	3.1
Explanatory variables (categorical)		
Near a direct bus line to UCLA	1 if living within half miles to a direct transit line to the campus; otherwise 0	66.5
Multimodal	1 if using more than one mode during the five survey weekdays; otherwise 0	50.8
Time of travel	1 if using the primary mode and not travel 7-9am or 4–6 pm; otherwise 0	66.9
Primary reason for choosing current residence	1-Transit proximity, living within a walking distance to a transit line	5.9
	2-Rent within budget	31.7
	3-Community amenities (safety, quiet neighborhood, green space, proximity to shops, bars, restaurants, etc.)	16.1
	4-Many friends or classmates live nearby	4.5
	5-Living with family	12.8
	6-Proximity to campus	26.6
	7-Other than the above (open answer)	2.4
Residence type	1-UCLA off-campus apartment	22.4
	2-Residence shared with other students or friends	36.4
	3-Home-stay w/an unrelated family	2.4
	4-Family's residence (Including parents' or student's own residence)	23.2
	5-Living alone	14.2
	6-None of the above (Open answer)	1.4
Parking permit	1 if having a long-term UCLA on-campus parking permit; otherwise 0	34.1
Transit pass	1 if having a UCLA-subsidized transit pass; otherwise 0	38.4
Undergraduate	1 if an undergraduate student; otherwise 0	44.9
Gender	1 if male; otherwise 0	41
Explanatory variables (continuous or ordinal) are		
Age	Age as of May 2010 Self-reported door-to-door commute time when using the primary mode	Mean: 26; *SD*: 6.0
Self-reported door-to- door commute time from home to UCLA when using the primary mode of travel (in min)	<10	2.7
	10–15	9.7
	15–20	6.0
	20–25	15.3
	25–30	13.2
	30–45	12.4
	45–60	19.3
	61–90	13.5
	>90	7.9
Commute distance	Network-based distance between one's home and UCLA	Mean: 14.48; *SD*: 114.63
Days at UCLA	How many days have passed since the respondent first registered at UCLA	Mean: 399; *SD*: 141
Observations: 508		

[a] Primary mode of travel that is used the most during the five consecutive survey weekdays (May 10th to May 14th 2010); if there is a tie for the number of days using two different primary modes, the primary mode used first would be treated as the primary mode in this study.

society/city where driving dominates, as indicated in Kerr et al. (2010). This intention makes them unconsciously ignore transit proximity when they determine their residence or prioritize their commute mode no matter how. If this is the case, there is plenty room for information contagion here.

5.7. Residence type

The self-reported residence type reconfirms that affordability matters the most to the students' residence choice. About 59% of the students live with others in a shared rental residence or in a university-owned apartment. These two residences in most cases are associated with a cheaper rent than an exclusive rental residence. There are also the students who are either comparatively richer or more family-oriented. Fourteen percent of the students reported that they exclusively occupy their residence and 23% indicated that they live with their family. Of the students living alone, only 23% reported that rent affordability is a primary concern (as compared to 32% for all the students who do not live alone). Of the students living with their family, when answering why they chose their current residence, 50% reported that is to live with their family, 20% for rent affordability and 20% for community amenities. Compared to the other students, the students living alone or with their family are more likely to drive alone to campus. Fifty percent and 61% of them drive alone to campus, respectively, while only 18% of the other students do so. A Chi-square *t*-test was used to determine whether there is a difference in mode choice between the students living alone (n = 80) and those not (n = 475) (Raw counts by mode for two group see Table 3).

This reveals a significant difference between mode choice of two groups, X^2 = 29.89 (df = 4, N = 200), p = 0.00, whereby the former have a significantly higher driving alone rate than the latter. Given all the above, it is likely that overall students living alone probably treasure privacy more and are able to afford to pay for it by driving alone and living alone. It is also possible that students living alone would receive fewer impacts of alternative-mode-related information contagion and interpersonal networks on their mode choice. In the future, of course, the above conjectures are worthwhile of further investigations.

6. Spatial analysis

Fig. 2 below shows the spatial distribution of the off-campus students' residences by mode choice on four maps of the same scale.

The maps show that:

First, as expected, alternative modes such as walking, biking and public transit are all significantly associated with residences within a distance of less than 20 miles from the campus. This is generally consistent with the finding of Shannon et al. (2006). Few students living a residence of more than 20 miles from the campus use these modes. In areas such as Bel Air, Beverly Park, Encino, the San Fernando Valley to the north of UCLA, no students commute by transit, bike or on foot. There areas are either some of the hilliest and most expensive neighborhoods (Bel Air, Encino and Beverly Park) in Los Angles and are separated from the UCLA campus by mountains (the San Fernando Valley).

Second, most students living more than 20 miles from the campus commute by driving alone. Almost all of the students who live more than 40 miles from the campus commute by driving alone.

Third, a distance such as 20 miles or more may prevent most students from using alternative modes; there were still, however, a few use these modes regardless of the distance. There are, also, a notable number of students drive to campus even they live in places where most of other students use alternative modes. This partially shows the dominance of driving across space in Los Angeles.

Fourth, regardless mode choice, a further check of all the student residences in another map (see Fig. 3) shows that most students live in a place where they can drive to campus by automobile within 45 min or less in the AM peak hours (7–9am). This indicates that most of the off-campus students still manage to live in places where they can drive to campus within 45 min, even in Los Angeles which has one of the highest housing and rental prices among all the US counties.

To test whether there is a difference in commute time distribution by mode, histograms were made. The histograms in Fig. 4 show the share of the respondents by mode of travel and by commute time band.

Fig. 4 confirms that driving alone shows up across all time bands, that is, it dominates across the space. There is steady growth in the share of public transit as the commute time increases when the time is smaller than 45 min. But this share notably declines as the commute time continues growing. The share of carpool is the most evenly distributed across different time bands of the four modes studied. As expected, most of the students commuting by bike or on foot have a commute time that is less than half an hour. What's a little surprising, however, is that some tiny share (less than 2%) of the students still bike or walk to campus even when the commute time is larger than 60 min.

Table 3
Counts by mode choice for the students living alone and those not.

Choice/count	Living alone	Not
Driving-alone	41	140
Public transit	22	148
Carpool	7	39
Biking or walking	7	133
Telecommuting	3	15
Total	80	475

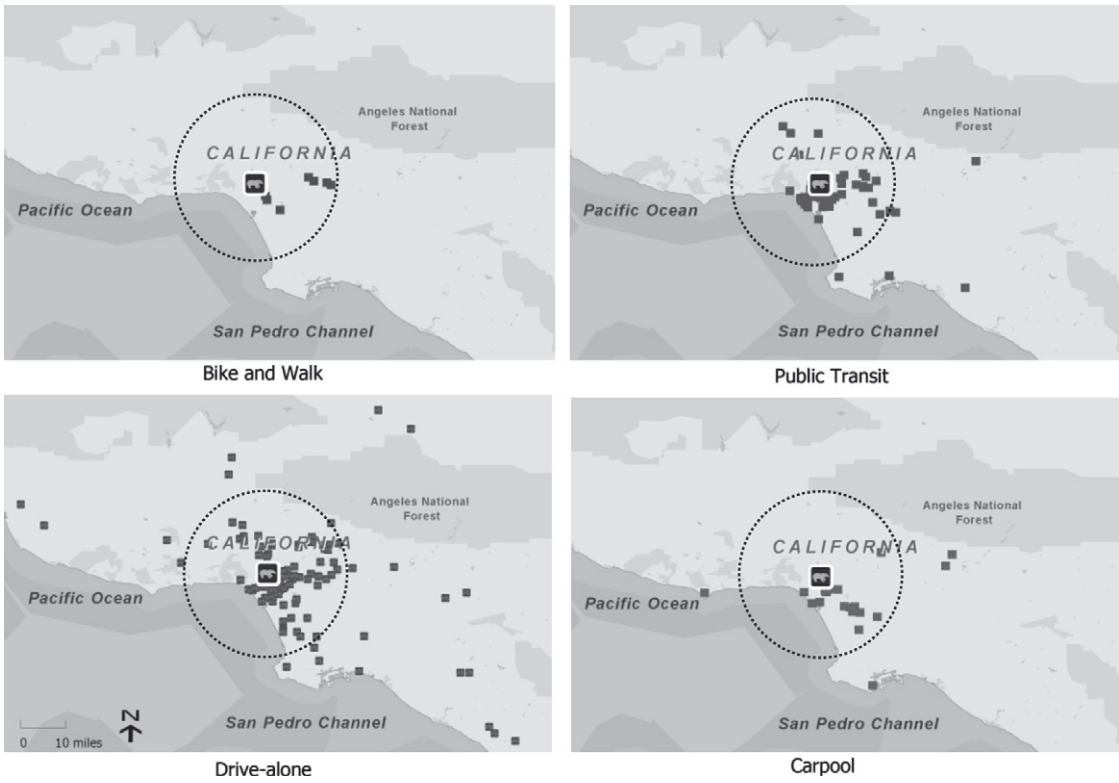


Fig. 2. Spatial distribution of the off-campus students' residences by mode choice. *Note*: *The bear symbol at the center of the circle represents the UCLA campus, the common destination for all the off-campus students. Each small square represents a residence. **The circle shows a 20-mile buffer area of the campus. ***Numbers of self-reported street intersections near one's residence that are geocodable: walk and bike = 128; public transit = 136; drive-alone = 138; carpool = 23.

To determine whether there is a difference in mean commute distance by mode, three unpaired student *t*-tests were conducted, with commute distances by driving-alone as the unchanged sample of the pair (see Table 4 below for summary statistics commute distance by mode).

The tests reveal that there is a significant difference in mean commute distances of driving alone and of transit and in mean commute distances of driving-alone and of biking or walking, whereby mean commute distances of transit and of biking or walking are significant shorter than that of driving alone. There is no significant difference in mean commute distances of driving alone, carpool and telecommuting. This indicates that residential distribution of the students who drive alone, carpool and telecommute is very similar.

7. Multinomial Logit Model

7.1. Mode description

The above quantitative and spatial analyses have disclosed some factors, especially residential location and residence type that might affect the students' mode choice. But they do not show when one specific factor changes how mode choice would follow and whether some factors have bigger effect on the choice than others. A Multinomial Logit Model (MLM) can provide this additional information.

Several researchers have contributed to the earliest development of MLM and several popular texts about MLM include McFadden and Reid (1974), McFadden (1976, 1980), Train (1986), and Ben-Akiva and Lerman (1985). Authors have used this model to study the mode choice of students and factors affecting it, for instance, Ewing et al. (2004) and Müller et al. (2008). MLMs allow one to look at probabilities or relative utilities of different mode choices. They also allow one to estimate the impact of different physical or individual factors such as travel time, transit proximity and income on a specific mode choice. Where there are unobserved factors at work with respect to similar mode choices such as vanpool and carpool, MLMs can be enhanced to Nested Logit Models (NLMs). Since this study has only five modes that are quite different and the sample size ($N = 508$) is not very big, a MLM rather than a NLM was used. In the case of this study's MLM, the probability that the ith student would choose jth mode choice is given by $P_{ij} = Pr(R_{ij} > R_{ik})$, for $k \neq j$, $j = 0, 1, 2, 3$, which represent different mode choices, with R_{ij} being the maximum utility attainable for student i if the student choose jth mode, and

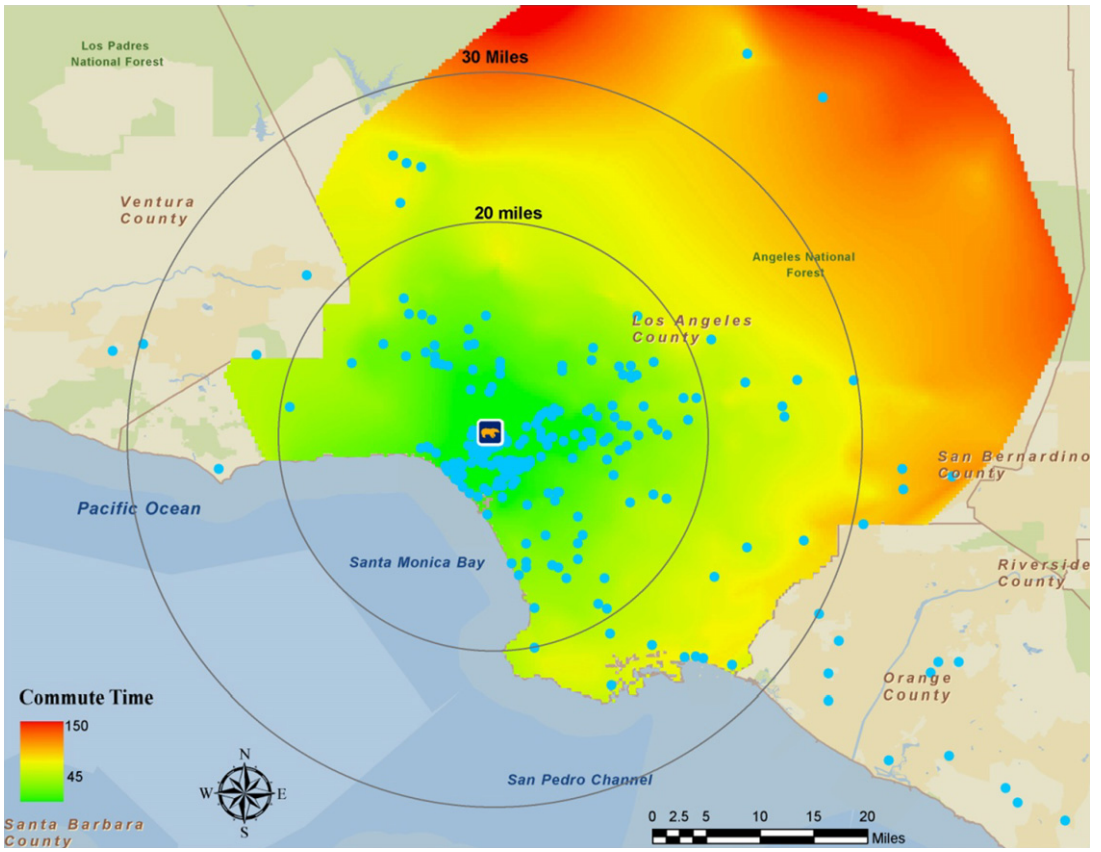


Fig. 3. Student commuters' residences and commute time in peak hours. *Note*: *Peak-hour travel times from different origins to campus are based on 400 UCLA employees' reported commute times by automobile in the AM peak hours (7–9am) on a typical weekday. ArcGIS 9.3's IDW tool was used to interpolate a surface of commute times where data points are not available.

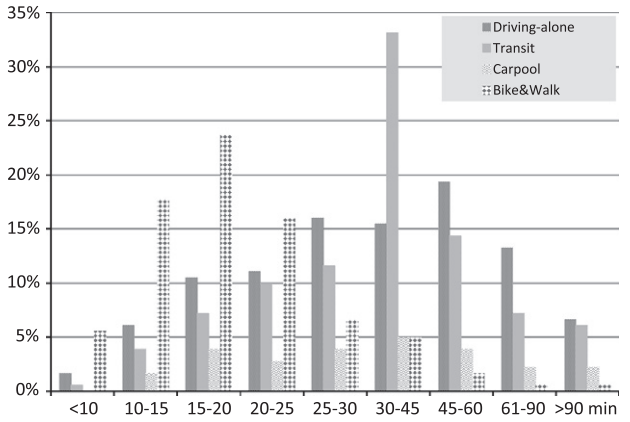


Fig. 4. Share of the respondents by mode of travel and by commute time band.

$$R_{ij} = \beta_j' X_{ij} + \varepsilon_{ij}$$

where β_j' is a vector of coefficients of each of the explanatory variables. If the If the stochastic terms εs have the independent and Weibull distribution, the MLM can be expressed as

$$P_{ij} = \exp(\beta_j' X_{ij}) / \sum \exp(\beta_j' X_{ij})$$

The parameters (βs) are estimated by maximizing a log likelihood function.

Table 4
Unpaired student *t*-tests of the mean commute distances by mode.

	N	Mean	*SD*	*DF*	*T*-stat.	Two-tail *p*
Driving-alone	181	14.50	14.89	–	–	–
Transit	170	5.38	6.44	248	7.52	0.000
Carpool	46	19.76	46.36	47	−0.76	0.451
Biking or walking	140	3.23	12.25	318	7.43	0.000
Telecommuting	18	174.33	624.15	17	−1.08	0.29

Given the variables about the student's characteristics highlighted in Table 2, the above MLM can be used to examine factors that affect the utility, odds, or benefits, of the students' mode choice and its influencing factors. Of course, we still need to assume that different mode choices, in this case, primary modes of commute such as driving-alone, carpool, public transit, walking and biking and telecommuting are independent of one another, as suggested by Ewing et al. (2004) and McFadden (1980).

7.2. Empirical results

To better use the data provided by the survey, two MLMs were developed. The first one studies the effect of the explanatory variables on the marginal utility of individual mode choices such as public transit, carpool, biking/walking or telecommuting relative to the reference—driving alone; the second one focuses on the effect of the explanatory variables on the marginal utility of alternative mode choices as a whole.

Given the total number of complete responses that can be used to construct variables for MLMs is relatively small ($N = 508$), the best-fit MLM results are chosen guided by the following principles:

- There are the as many as explanatory variables that would plausible impacts on mode choice as possible so as to better understand how different factors influence mode choice, at least the sign of their respective impacts.
- Inclusion of one additional explanatory variable other than those used would not increase the McFadden *R*-square value greater than 0.05.

SPSS 19, a popular social statistical software package was used to generate the MLM results and the results are presented in Tables 5 and 6.

The coefficients in Table 5 show the effects of the explanatory variables on the marginal utility of alternative mode choices such as public transit, carpool, biking/walking and telecommuting relative to the reference—driving-alone.

The coefficients on parking permit are highly significant across all alternative modes and the negative sign suggests that having an on-campus parking permit reduces utilities of all alternative modes. This is consistent with our conventional knowledge: in most if not all cases, rational commuters whose primary modes are alternative modes would not spend money on an on-campus parking permit that they never or rarely use. The coefficients on transit pass are highly significant for transit, carpool and biking or walking. The positive sign suggests that having a discounted transit pass increases the utility of public transit, carpool and biking or walking. It is understandable that having a discounted transit pass increases the utility of transit, because most rational students taking public transit would not miss the opportunity of getting a discounted transit pass, letting alone a pass receiving 50% subsidy at UCLA. What's a little surprising, however, is that having a discounted transit pass also increases the utility of carpool, biking or walking. It is likely that those students who carpool, bike or walk occasionally use public transit in situations such as the carpool partner is not available or there is bad weather. The coefficient on near a direct bus line for biking or walking and the coefficient on multimodal for carpool and transit also further confirm this, which show that living near a direct bus line significantly increases the utility of biking or walking and that being multimodal significantly increases the utility of carpool and transit.

Four of the coefficients on primary reason why a student chose his/her current residence are highly significant for the mode of public transit. The positive sign across primary reasons suggests that transit proximity, rent affordability, many friends and classmates living nearby and living with family all increase the utility of public transit. Here, many friends and classmates living nearby and living with family could potentially increase the effects of information contagion or interpersonal networks. Due to survey design and data availability, however, this study is unable to make any definite conclusions. But the above correlation plus the significant difference in driving alone rate between those living alone and those not jointly engender an interesting question to be further explored. Little has been done on this question before, as highlighted in the literature section. The effects of transit proximity are generally consistent with the finding of Boyd et al. (2003).

The coefficients on commute distance are highly significant for carpool and telecommuting. The positive sign and the small values of the coefficient suggest that as commute distance increases, the utility of carpool and telecommuting slightly increases as well. Given the relatively small sample sizes of the carpool and telecommuting students used in the model, one has to be a little cautious here regarding the above findings, as they can simply be statistical artifacts. The findings, nevertheless, are still consistent with our conventional knowledge, at least for the correlation between telecommuting and commute distance: the longer the commute distance is the more likely one would telecommute.

Table 5
MLM estimates for transit, carpool, biking or walking and telecommuting: comparison with driving-alone.

Variables	Code	Transit coefficient (N = 157)	Carpool coefficient (N = 43)	Biking or walking coefficient (N = 126)	Telecommuting coefficient (N = 16)
Interception	–	14.01	−2.33	−14.01	0.72
		(0.00)	(1.22)	(0.00)	(0.04)
Near direct bus line	1	0.17	0.17	1.76**	−0.58
		(0.12)	(0.10)	(5.59)	(2.17)
Multimodal	1	0.72**	1.07***	−0.02	−.075
		(4.319)	(6.72)	(0.00)	(0.97)
Time of travel	1	0.62*	−2.59	0.33	–
		(3.11)	(0.40)	(0.64)	
Primary reason	1	18.49***	1.78	0.30	−13.56
		(522.30)	(1.32)	0.01	(0.00)
	2	17.47***	0.54	−0.100	−1.07
		(1145.17)	(0.16)	0.00	(0.60)
	3	18.07	0.60	0.06	0.13
		(964.82)	(0.18)	.001	(0.00)
	4	18.80***	1.51	1.67	−12.99
		(364.14)	(0.89)	.561	(0.00)
	5	17.50***	0.76	−13.41	−1.68
		(452.01)	(0.27)	0.00	(1.31)
	6	18.34	1.89	2.68	0.99
		(0.00)	(1.82)	1.63	(0.38)
Parking permit	1	−2.44***	−1.22***	−3.00***	−3.08***
		(38.93)	(8.43)	(30.57)	(12.94)
Transit pass	1	2.43***	0.93**	1.31***	0.52
		(41.10)	(3.99)	(8.74)	(0.39)
Undergraduate	1	−0.10	−0.23	1.28**	−1.81*
		(0.05)	(0.22)	(6.52)	(3.20)
Gender	1	0.51	−0.42	1.34***	0.52
		(2.16)	(0.98)	(10.64)	(0.58)
Age	–	−.075***	−0.02	0.08*	−0.13
		(6.33)	(0.37)	(2.90)	(2.01)
Commute distance	–	−.016	0.026**	0.02	0.03***
		(0.49)	(6.37)	(0.22)	(7.73)
Days at UCLA	–	0.002	0.002	0.00	0.00
		(1.54)	(0.96)	(0.67)	(2.17)

Notes: Z-statistics are given in parentheses below. Driving-alone is the reference mode, for all modes N = 508. McFadden R^2 = 0.427.
* Significance of 10%.
** Significance of 5%.
*** Significance of 1%.

The coefficients on undergraduate are highly significant for carpool and telecommuting. But different signs indicate that being an undergraduate would increase the utility of biking or walking but decrease the utility of telecommuting. In other words, undergraduates are more likely to bike or walk to campus and while graduate students are more likely to telecommute. The coefficient on gender shows that being female significantly increases the utility of biking or walking. Since the survey response does not differentiate biking and walking, it is unclear whether the above effects are equal between biking and walking. This can be an interesting question for future investigations.

The coefficients on age are highly significant for public transit and biking or walking. The negative sign for public transit reveals that the older one is the fewer utilities public transit would provide him or her. This may be explained by facts such as being older also means (a) more job and household responsibilities, (b) a higher demand for a car to get around in a car-dominant place like Los Angles and (c) more disposable income for transportation and thus car ownership and related expense are no longer an issue. Unfortunately, the survey does not collect any such information and this has to be done in the upcoming surveys and studies.

Overall, the coefficients and levels of significance of them in Table 5 statistically validate many of our existing conjectures about students' alternative mode choices rather than providing new empirical evidence to rebut them.

The coefficients in Table 6 show the effects of the explanatory variables on the marginal utility of alternative mode choices as a whole relative to the reference—driving-alone. Most of the effects and the signs and significance levels of the coefficients are in consistent with what has been presented above, for instance, being multimodal and having a discounted transit pass increase the utility of alternative modes while holding a parking permit reduces the utility of alternative modes. But the coefficient on proximity to campus does provide some contradictive information. The positive sign of the coefficient indicates that proximity to campus increases the utility of alternative modes (p = 0.1). As discussed above, however, commute distance is positively related to the utility of carpool and telecommuting (p = 0.05 or p = 0.01). This contradiction

Table 6
MLM estimates for the alternative modes: comparison with driving-alone.

Variables	Code	Alternative mode coefficient (N = 342)
Interception	–	14.01
		(0.00)
Near direct bus line	1	0.38
		(0.91)
Multimodal	1	0.52*
		(3.31)
Time of travel	1	0.28
		(0.88)
Primary reason	1	1.17
		(0.98)
	2	0.10
		(0.11)
	3	0.56
		(0.30)
	4	1.54
		(1.46)
	5	−0.24
		(0.05)
	6	1.80*
		(2.90)
Parking permit	1	−2.30***
		(56.57)
Transit pass	1	1.68***
		(25.64)
Undergraduate	1	0.08
		(0.05)
Gender	1	0.38
		(1.73)
Age	–	0.06**
		(5.37)
Commute distance	–	0.22**
		(0.04)
Days at UCLA	–	0.001
		(1.12)

Notes: Z-statistics are given in parentheses below. Driving-alone is the reference mode and alternative modes include transit, biking, walking, carpool and telecommuting. For all modes, N = 508. McFadden R^2 = 0.463.
* Significance of 10%.
** Significance of 5%.
*** Significance of 1%.

implies that (a) the caution highlighted above about the interpretation of the coefficients when sample sizes are small is legitimate; (b) more jobs to be done to better understand the effects of commute distance or proximity to campus on alternative mode choices as a whole and individual alternative mode choices.

8. Discussions and conclusions

Universities and colleges play an important role in producing, synthesizing and conveying knowledge, ideas and technologies that shape or characterize our society. They help reshape the behavior and mindset of future generations. They are also in many cases a large trip generator in cities or counties where they reside. Millions of university and college students commute like the general population but we know little about their mode choice and its influencing factors. Using data from UCLA, a university in a place notorious for car dominance, this study has investigated a wide array of factors that influence alternative mode choices of university students. It confirms some existing findings in a new context, validates many of our existing conjectures about university students' alternative mode choices and provides new insights into some "additional" factors' effects on university students' alternative mode choices.

In particular, in light of the research questions posed, this study finds that being embedded in Los Angeles does not make university students drive alone more than their peers in other places. It shows that being multimodal and having a discounted transit pass increase the utility of alternative modes such as public transit, biking, walking, carpool and telecommuting while holding a parking permit reduces the utility of these modes. Commute distance probably has a mixed impact on the utility or odds of these modes. This study identifies that commute distance is positively related to carpool and telecommuting. It cannot confirm that commute distance and biking, walking and usage of public transit are significantly correlated (cf., Shannon et al., 2006; Gould et al., 2007; Collins and Chambers, 2005). It shows that most students

commute during the off-peak hours. It shows that gender, status (undergraduate vs. gradate) and age are significantly correlated to biking, walking or usage of public transit. Some of the above findings are in general consistent with those in existing studies, for instance, transit pass increases the odds of alternative modes such as transit (cf., Boyd et al., 2003). Others seem to be new findings that have not presented in existing studies reviewed, for instance, being multimodal increases the utility of alternative modes such as transit, biking, walking, carpool and telecommuting. Students living alone are more likely to commute by driving alone than other students. Having friends and classmates living nearby increases the utility of public transit. Due to data constraints, this study cannot prove whether there is any correlation between information contagion and the effects of living alone and having friends and classmates living nearby on alternative modes. But it proposes that the issue be worthwhile of further investigations in light of the theories of information contagion and TPB and the models of MaxSem and NAM.

As a whole, the above findings of this study indicate that to better promote alternative modes of commute among students at universities one should consider the following:

- *A comprehensive TDM program.* This study particularly shows discounted transit pass significantly increases the utility of transit, biking, walking and carpool. It also shows that having an on-campus parking permit would significantly increase the driving alone rate. To increase the effectiveness of TDM programs, one should also emphasize early, accurate and person-to-person TDM information supply and assistance, as what was done at Monash (Rose, 2008).
- Utilization of information contagion effects among students. This study shows that not living alone or having friends or classmates living nearby increase the odds of using alternative modes in general or taking public transit in particular. Thus, this at least indicates that promotion of alternative modes should care about various means to encourage students live with or near other students. Member-only informational exchange platforms thus can be considered. At UCLA, for instance, Zimride is one of such platform.
- Promotion of multimodal commute among students. This study shows that as many 51% of the students at UCLA are multimodal. This study also shows that being multimodal increases the utility of alternative modes such as transit and carpool. The promotion can be materialized in the forms such as discounted daily permits for students who usually commute by an alternative mode but occasionally drive to campus and dynamic rather than flat parking fees for students driving to work. Such dynamic fees take into account how frequent and how long students use an on-campus parking space and refund partially their prepaid parking fees if they significantly reduce their occupancy of the space. The other form can be like "Dump-the-Pump" described in (Zhou and Schweitzer, 2011), which is a program providing a 12-week free trail of public transit to driving commuters who are willing to temporarily surrender their on-campus parking permit.

This study, of course, can be improved in several aspects after re-examining the survey data and unresolved questions due to missing data or information. First, it could have sent the survey instrument to more students of several local universities so that there could be more responses/samples. With a relatively small sample at one university, the reliability and transferability of this study's conclusions can be challenged. Also, it is hard to tell whether UCLA students are unique in terms of their housing patterns and mode choice characteristics and factors influencing these. At UCLA, for instance, there is already a rather comprehensive TDM program in place. The impacts of this program on UCLA employees' commute have been proved to be significant (Zhou et al., 2012). Of course, across-university surveys would require more labor and time investment. Making across-campus comparisons would also require sophisticated research design to arrive at reliable conclusions.

Second, the survey conducted to support this study could have included more questions such as students' income level (many students may have a part-time job), car ownership or access and how their peers' travel behaviors have affected their mode choice. Answers to these questions would allow the study to look deeper into issues such as how the residential and mode choices of the student are influenced by their job location, how car ownership or access affect alternative mode usage and whether and to what degree information contagion influences alternative mode choice.

Third, this study could have collected more information about acceptable rent level, residence/mode preferences, environmental awareness and residential locations among the students. It could also have compared the existing housing choice of the students with what is available in the market. This would allow the author to better understand constraints and opportunities faced by the students when making transportation and housing choices. Such understanding would provide references for policy inventions and information assistance that would increase the rate of alternative modes among the students.

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