ANALYZING HOUSEHOLD LIFESTYLES, MOBILITY AND ACTIVITY PROFILES: A CASE STUDY OF SINGAPORE

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Word count: 6000
Number of figures: 6
Total number of words: 6000+6*250=6075+1500=7500

Submission Date: August 1, 2012.
ABSTRACT

Due to data constraints and computational complexity, activity-based modeling tends to focus on the daily activity schedule of individuals without much attention to household effects. However, the timing, mode choice, and destinations of an individual’s daily travel are often constrained by household considerations. This paper uses data mining and visualization techniques to interpret data from a traditional travel survey of Singapore residents in order to identify common activity profiles and mode choice patterns. The goal is to find ways to link household demographics and ‘lifestyle’ choices to the daily activity patterns of individual members in ways that are plausible and computationally practical for travel demand modeling. Households are differentiated by size and age composition, and then principal component analysis and clustering techniques are used to identify their dominant combinations of activity patterns by time of day and mode. The results suggest that household constraints on the timing and mode choice of individual daily schedules can be characterized in terms of household ‘lifestyle’ profiles that bundle particular combinations of residential location, mode options, destination choices, and trip timing.

Keywords: Household Lifestyles, Lifecycles, Activity Profile, Cluster Analysis, Singapore
INTRODUCTION

In recent years, workforce changes, economic and demographic trends, and improved mobility have limited the applicability of traditional trip-based four-step models and motivated increased interest in activity-based modeling. Multi-worker families, increased employment turnover rates, firm fragmentation and decentralization, and rising income have complicated travel demand modeling. Researchers can no longer assume that household location, trip generation, and mode choice can be estimated, in that order, based principally on the work location of the household’s primary worker. Which worker gets the car? Who picks up the kids? When do we do the shopping? Household decision making is becoming more complex and likely to involve interactive communication, negotiation or even compromises among household members, especially on issues of where to live, what type of vehicles to purchase, etc. These choices are usually made by the household to achieve its overall goals and may not be easily related to one individual member’s values, attitudes, and perceptions. Ultimately, different households may place different emphasis on factors such as obtaining the best possible quality of education for the kids, accommodating work and leisure preferences, or balancing the travel time and cost of workers in the household.

While researchers recognize the importance of household interactions in these locational choices and activity patterns, data constraints and computational complexity are significant. As a result, activity-based modeling tends to focus on the daily activity schedule of individuals without much attention to household effects. However, the timing, mode choice, and destinations of an individual’s daily travel are often constrained by household considerations. This paper uses data mining and visualization techniques to interpret data from a traditional travel survey of Singapore residents in order to identify common activity profiles and mode choice patterns. Households are differentiated by size and age composition, and then principal component analysis and clustering techniques are used to identify their dominant combinations of activity patterns by time of day and mode. The intention is to find improved methods for linking household demographics and ‘lifestyle’ choices to the daily activity patterns of individual members in ways that are plausible and computationally practical for travel demand modeling.

LITERATURE REVIEW: LIFESTYLES AND ACTIVITIES

In order to understand why household interaction and lifestyle choices can be important to activity-based travel analysis and modeling, as well as to urban planning, we first review related studies on “lifestyles” conducted by researchers in various disciplines (i.e., marketing, cultural, environmental, and urban and transportation studies). Next, we look at theoretical and empirical studies on activity-based analysis and modeling. Based on the assessment of the existing literature, we then identify aspects of the intrinsic links between household lifestyles, mobility and activity behavior that might be identified from data in traditional travel surveys. Subsequent sections use one-day travel diaries from a 1% sample of Singapore household to extract common patterns of activity scheduling and mode choice among individuals within three- and four-person households.

Lifestyles: Concept, Definition, Measurement, and Estimation Methods
As human beings, our behaviors, in various ways, are the manifestation of our values, attitudes, habits and perceptions that we carry, and of the lifestyles we are associated with. A dictionary version definition of lifestyle is “the habits, attitudes, tastes, moral standards, economic level, etc., that together constitute the mode of living of an individual or group” (1).

Due to its importance in guiding individual and groups of individuals’ behavior, the topic of lifestyle has been widely explored in various realms in the past, including marketing (2, 3), political science (4), psychology, sociology, and anthropology (5, 6). For example, in the marketing field, it is important to understand the market segmentation in terms of consumers’ ability and desire to buy products and services. For example, a recent analysis on Values and Lifestyles Scale (VALS) concluded eight types of US consumer lifestyles as innovators, thinkers, believers, achievers, strivers, experiencers, makers, and survivors (7). Some studies also looked at lifestyles that influence a particular market segment. Fraj and Martinez (3) looked at the ecological market, and found that people who have the ecological lifestyle (i.e., people who are environmentally conscious) have environmentally friendly behaviors. On the other hand, lifestyles and values may also change over time with the cohort effect. A recent study on personal values in the west European societies from 1970 to 2006 suggested major intergenerational value and cultural changes during the 35 years (5). Even though the above studies did not tackle urban questions directly, they are informative to urban researchers in a sense that people’s values and attitudes, reflected in their consumption and behavior, also influence the way they live, work, play and travel. Hence, urban planners must be concerned with these aspects in order to plan sustainable and ‘smart’ cities that accommodate people’s discretionary choices about how they live.

Researchers in the urban and transportation arenas have also investigated the role of lifestyle in individual and households’ behavior, in terms of residential location choices (8), vehicle ownership choices (9), travel demand and patterns (10-15), activity participation and patterns (16), energy demand and related emission (17), etc. For example, Salomon & Ben-Akiva (1983) defined 5 types of lifestyle segments (i.e., the upper socioeconomic classes with large and small households, the younger group, a socioeconomic class with lower income/education, and an elderly class) by employing cluster analysis method. Kitamura (10) suggested that lifestyle can be revealed by consumer expenditure patterns, life-cycle stages (e.g., couples with/without children, single individuals/parents, etc.), social demographic characteristics (e.g., age, sex, employment status, income), car ownership, and travel environment (consumer technologies and products, telecommunications, urban systems). Using a similar set of measurements, including travel characteristics, activity frequency, automobile ownership and urban form, Krizek and Waddell (18) used factor analysis to cluster households in the King, Snohomish, Pierce, and Kitsap Counties in the U.S. into nine segments (including retirees, single/busy urbanists, elderly homebodies, urbanists with higher income, transit users, suburban errand runners, family and activity oriented, suburbanites with double income, exurban family commuters). Employing a latent class choice model with attitude indicators, while estimating residence location choice, Walker and Li (8) simultaneously estimated three classes of household lifestyles, namely (a) suburban, auto, school orientated, (b) transit, house orientated, and (c) high density, near urban activity, and auto orientated. Using behavioral mixture models captured by latent class, and a longitudinal data set, Vij et. al. (14) studied a sub-dimension of individual’s lifestyle, the modality style, by quantifying its influence on individuals’ long-term mode choices for both work and non-work related travel. To summarize, in the current literature,
household lifestyles are manifested by their members’ behavioral patterns, household formation, labor force participation, location choice, and leisure orientation (8, 16, 18).

Activity Based Approach

Different facets of human activities have been studied widely by researchers in sociology, social ecology, psychology, economics, and urban and transportation studies. The activity-based analyses that influenced today’s development of activity-based travel demand modeling and originated from the 1970s were pioneered by geographer Hägerstråand and urban sociologists Jones, and Chapin, et al. (19-22). They explored human activities and travel patterns in time and space, followed by a group of geographers with different approaches, perspectives and data collection methods (23-27). A further development with the activity analysis legacy in the transportation field, on the other hand, shifted the paradigm of travel demand modeling from its traditional trip-based approach to an activity-based approach (28), with the view that travel is derived demand in pursuit of activities (22).

Beyond its origin of activity-based analysis, works that examined the linkages between the short-term individual/household daily activity and travel patterns, and the long-term household location choice (of housing and job) and vehicle ownership contributed to the development of activity-based modeling. For example, Lerman (29) by employing a multinomial logit model, studied the relationships between residential location, housing type, auto ownership and travel mode to work. Among other studies which extended this approach (16, 30-35), Bowman and Ben-Akiva(16, 36) developed a prototype discrete choice model system for Boston to integrate household’s residential location choice with models of activity and travel (consisting of tours, characterised by destinations, time of day and travel modes, etc.) by supplying each household member the utility-based accessibility measure estimated from the activity and travel models. This approach has been adapted by several U.S. MPOs for activity-based demand modeling (37).

HYPOTHESES, THEORY AND FRAMEWORK

Household Lifestyles and Long-Term Household Choice Package

In this section, we try to make two arguments about household lifestyles, mobility and activity profile choices in their long-term decision making processes. First, we stress that the unit of analysis for long-term behavior choices should be households instead of individuals. Second, we argue that the long-term household choices should be a package of residence/job/school location, vehicle ownership, household mobility and activity profiles, which reflect the household’s values, attitudes and perceptions—or the household lifestyle.

Household Lifestyles v.s. Individual Lifestyles

One of the reasons why households should be considered as the unit of analysis when we examine the long-term household decision making process is because we humans are social beings, and we need to play certain roles, to take care of certain relationships, and to take certain responsibilities in our household. Based on the discussions in the previously mentioned studies in the literature (13), we know that household choices on residential location, work/school location, or vehicle ownership are usually resulted from household members’ interactive communication, negotiation or even compromise, and reflect the values, attitudes and
perceptions of the household as a whole. Meanwhile, we also notice that families guide individual members to their beliefs, values, and lifestyles. These values, attitudes, and perceptions of the individuals, and their role and responsibilities in the household together restrict and shape their behavior.

**Long-Term Household Choice Package: Location, Vehicle Ownership, Mobility, and Activity Profile**

We also argue that households’ mobility and activity profile choices to a great extent should be included in a package of the long term household decision making process, in which households choose a typical way of living, working, studying, playing, and traveling, in addition to the location and vehicle ownership choices. In fact, when households choose a location of residence/work/school, as well as a certain type of vehicle, the household is choosing a potential way of living for every household member, which includes the long-term activity participation, and travel. And these long-term choices are influenced by the household’s lifestyle.

Since the choices on residential/job/school location, and mobility and activity in the long term are often intertwined together, and are fundamentally influenced by the values and attitudes of the household as a whole, we argue that when considering households’ long term decision making process, we should treat household location, mobility and activity profile choices as a package, whose components would be simultaneously influenced by household values, or lifestyles. For these reasons, an outcome of an individual’s long-term choices on his or her mobility (e.g., whether one should depend on a car for his/her travel, or be an environmental advocate to rely on bicycles) and activities (e.g., whether one should go to work early and come back home early) may not result from his or her own utility maximization process, but from the needs, values, and attitudes (or lifestyles) of the household as a whole.

**Household Mobility Profile**

**Concept**

By household mobility profile, we mean a general travel modal plan in a long-term period (e.g., on a yearly basis) chosen by a household for its members. It is more general than the medium-term level mode choice decisions on a daily basis. Theoretically, this long-term mobility profile provides the basis or the condition of daily-based travel mode for individuals of the household, while it allows variability in mode choices of individuals of the household in a particular day for a particular travel purpose in the medium-term level (on a daily basis). For example, in a household with no cars, with two working parents and one school-aged young kid, the mobility profile of the household could be that the commuting trips for the parents are by bus and railway, and non-work related trips are by car sharing; for the kid, walking and riding the school buses are the major modes for her to go to school and to return home. The possible factors that drive the household to choose this type of mobility profile in the long-term may include their household values and attitudes (or lifestyles), their social economic level, demographic characteristics, household lifecycles, and the types of activities they are interested in engaging in, etc.
Measurement and Method

To measure the household mobility profile that we introduced here, two major components are being considered, (1) the types of modes and (2) the types of trips that engage the usage of a particular type of modes by household members as a whole. To incorporate these two aspects, we need to rework the travel survey data into a format that has the household as a unit of analysis. That is, each row in the reconstructed data set represents a household and the columns indicate, for each type of trip, whether and how many trips household members take that involve that particular kind of mode for that type of trip. By applying the K-mean clustering algorithm on this derived data set, we will be able to cluster household mobility profiles, and understand the mobility choice decisions that household make as a whole for the long-term. The interpretation of the reformatted data will become clearer in the Case Study section when we explain the specifics for the Singapore travel survey.

Ideally, a longitudinal data set that records travel behavior of household members can reveal the long-term mobility profile choices best. However, since many of the available data sets accessible to researchers on households’ travels in most metropolitan areas are cross sectional in nature due to the limitation in data collection, when we use cross sectional type of data to derive long-term household choices, we implicitly make an assumption that the observed behavior at a given day is a manifestation/representation of a long-term decision on households’ mobility profiles. With the increasingly fast development of information and communication technologies (IC&T), the barriers of collecting longitudinal data on household travel and activities may reduce, which will enable researchers to get better sources of data on the long-term household behavior, and allow us to have a more accurate understanding of household long-term choices in the future.

Household Activity Profile

Concept

The idea that household activity profile is a choice of the long-term household decision outcome influenced by household lifestyles was inspired by early studies which maintain that time-use behavior of individuals’ activities can reveal their lifestyles (38, 39). By household activity profile, we mean the combination of primary activities and the general time-of-day to conduct the primary activities in a typical day for members in a household. We believe this is a long-term level decision rather than a medium-term level decision as activity participation of household members is a intertwined choice when household make the decision on where and how to live, work, and play. Using the same example provided in the household mobility profile section, a family with two working parents and a young kid can have a household activity profile with one person engaging in early-day working activity, one engaging in regular-day working activity, and one engaging in morning schooling activity. It is worth noting that, none of the previous studies on household lifestyles and long-term household behavior analysis investigated this aspect. And we want to capture the time-of-day effects on primary activity participation as a manifested long-term household lifestyle.
Measurement Method

The two major components of the activity profile are (1) primary activities and (2) time-of-day conducting the primary activity by each member of the household. To capture these two pieces of information, we adapt the method developed and illustrated in a study on clustering individual’s daily activity patterns in Chicago by Jiang et al. (40). In the Chicago study, Jiang et al. applied the K-means algorithm via PCA method to a binary temporal activity data set (which indicates whether an individual is engaged in a particular activity during a particular time interval) derived from the 2008 activity-based travel survey designed and conducted for the Chicago Metropolitan area. By clustering individuals into different groups according to their daily temporal activity patterns in the Chicago Metropolitan Area, Jiang et al. found there existed eight groups of activity profiles in the Chicago metropolitan area, including early-bird working, regular-hour working, late-hour working, morning adventuring, evening adventuring, overnight adventuring, staying at home, and day schooling individuals.

Extending the Chicago study by Jiang et al. (40), we propose to cluster households activity profiles into segments based on the combination of the potential eight types of individuals’ activity profiles within a household as the household activity profile. Two possible approaches can be applied here. First, we can derive a discrete temporal activity data set, from the usual household travel survey, which indicates whether and how many household members are engaged in a particular activity during a particular time interval. We can then apply the same K-mean via PCA method demonstrated by Jiang et al. to cluster household activity profiles into segments. Second, we can first cluster individuals’ activity profile into groups, and then cluster the derived discrete measure on how many household’s members belong to each individual activity profile group within a household. The segmentation of the household combination of individual activity profiles can also be employed to measure the household activity profiles. With an illustration using Singapore as an example, the readers may understand more clearly how to implement the measurement of household activity profile that we propose here in later sections.

CASE STUDY: SINGAPORE

The Singapore Context

In this paper, we use Singapore as a case study to demonstrate how we can probe household lifestyles by analyzing the different mobility and activity behaviors, socioeconomic, and demographic characteristics of households. By 2011, Singapore has a population of 5.18 million (among which 3.79 million were Singapore residents, including 3.26 million Singapore citizens and 0.53 million Singapore permanent residents), land area of 714.3 square kilometers, and a population density of 7,257 persons per square kilometer (41). To give the readers a general sense of Singapore in terms of its urban and transportation environment, Figure 1 exhibits different views of the city-state of Singapore.
Figure 1 Singaporean neighborhoods, housing and transportation: (a1)-(a3) traditional neighborhoods with a mix of pedestrians, motorcyclists and auto drivers/passengers; (b1)-(b3) housing and transportation options of the HDB neighborhoods, (c1)-(c2) landed and private properties along the elevated MRT line, and (c3) an underground MRT station platform. (Source: authors).

(a1) to (a3) in the first row of Figure 1 show the traditional neighborhoods, with pedestrian friendly walking environment, and are also welcomed by users with various modes such as bikes, motorcycles, and automobiles. (b1) to (b3) in the second row show a neighborhood of public housing developed by the Singapore Housing and Development Board (HDB), the vehicles parked on the surface in the neighborhood, and the surrounding public transportation facility (such as bus stops or transit stations). (c1) to (c2) in the third row show some landed properties and private developed properties (not developed by the government) along an elevated Singapore Mass Rapid Transit line. (c3) is a view of an MRT station platform in the rush hour of a regular morning. We can see that Singapore is mixed with fairly high density of housing, and public transportation facilities, and has no extreme cases in terms of the spatial distribution of urban neighborhoods. On the other hand, there are various government policies in the public housing purchasing processes overseen by HDB, and regulations and management of vehicle registration, congestion charging during different time of day, and public transit planning are done by the government agency of Land and Transport Authority (LTA), and urban development and planning at different levels by the Urban Redevelopment Authority.
Data

In this study, we employ the most recent 2008 Household Interview Travel Survey (HITS) designed and collected by the Singapore LTA to analyze the household behaviors that we believe are influenced by household lifestyles in Singapore. The 2008 HITS data collection was from June to November 2008, and January to March 2009. With a sample size around 1% of the total households in Singapore (more than 1 million in 2008), 10,725 households completed the survey. The 2008 HITS surveyed the then legal residents of Singapore, including Singapore citizens, Permanent Residents, Employment Pass holders, Student Pass holders, Work Permit holders and Dependent Pass holders, and was conducted by face-to-face interview with all eligible members of the households about their travel on a typical weekday (Monday to Friday). If more than one member of the household remains unreachable after 4 attempts, LTA would replace the original household with a one of the same dwelling type.

As Fridays get closer to weekends, people tend to have different travel and activity behaviors than on Mondays to Thursdays. Therefore, we selected only households that reported their travel and activities from Monday to Thursday, as well as those whose members were interviewed on the same day (to help us sort out the household lifestyle effects on their long-term mobility and activity profile choices). We also eliminated household samples whose member(s) reported their travel time for one trip was greater than 5 hours, as we believe those records were errors given the size of Singapore. After applying these above standards, we got a sample of 6,809 households whose members had travel and activities on the same representative weekday (Monday to Thursday), including a total of 24,297 individuals (for those who were under 4 years old, they did not report their travel or activities) in the 2008 HITS survey.

Figure 2 is a collection of snapshots of activities in which individuals are engaged (or travelling toward) at different times of day in Singapore on the above defined “representative weekday”, with different colors encoding their different types of activities and a Google map of Singapore in the background. We can see that at 7:00 o’clock in the morning, students have already started their travel to school and some people started their travel to work but not many, and the majority Singaporeans are still at home. Around 1:00 o’clock in the afternoon, the center of Singapore, its east cost, and along its major west corridor, it has been populated with people who engage in work activities; meanwhile students are at school in different parts of Singapore. There are also some hot spots with heavily concentrated shopping and recreational activities in Jurong West, a big residential center in the western part of Singapore, and in various downtown areas. At around 7:00 o’clock in the evening, most of the students have gone back home with only those in the university areas still engaging in educational activities, while there are still many people working in the center of Singapore, and some shopping activities in the Orchard road area, which is the biggest shopping district in Singapore. Activities with the synonym of “rec” in Figure 2 include eating meals outside of home, recreation/entertainment, sports/exercise, and social visit/gathering. They are colored in cyan, and distributed all over Singapore. To give a background of this phenomenon, readers may want to know that there are at least one or two community dining centers around most of the established neighborhoods in Singapore. Meanwhile due to the hot weather, Singaporeans tend to eat outside of home rather than cooking and dining at home, plus the price of eating out in the community dining centers are often very affordable and competitive with the cost of cooking at home.
Figure 2 Snapshots of human activities at different time-of-day in Singapore on a representative weekday.

FINDINGS: SINGAPORE HOUSEHOLD MOBILITY AND ACTIVITY PROFILES

In this section, we present our analysis results on Singaporean household mobility and activity profiles influenced by their household lifestyles. These analyses are all based on the “representative weekday” sample as described in the previous section on data description.

Household Lifecycles in Singapore

Here we introduce worth noting concept of household lifecycles, closely related to yet different from the concept of household lifestyles. According to Kitamura (10), household lifecycles are indicators of social roles presented in different households, typically defined by age and marital status of the adult members, and presence and age of the children of a household (e.g., couples with/without children, single individuals/parents, etc.) Household lifecycles are important as it associates with various roles that household members play.

In the case of Singapore, since we don’t have marriage status data for household members in the 2008 HITS survey, we try to use age distribution of households with different sizes to understand the general household lifecycles in Singapore. Among the 6809 qualified household samples, 8.9% households are with only one member, 18.1% with two, 21.4% with three, 25.6% with four, 15.9% with five, 6.6% with six, 2.4% with seven, 0.8%, 0.1%, 0.1%, and less than 0.1% with eight, nine, ten and eleven household members, respectively. We can see that the composition of Singaporean households are much more complicated than those we see in the Western society due to cultural differences. In some cases, a household may have several generations, including senior parent(s), adult parent(s), and young children.

Figure 3 exhibits the kernel smoothing probability estimation on both the probability distribution functions (pdf), and the cumulative distribution functions (cdf) of age for households
with different sizes from one to six (given that they accounts for 96.5% of all households in the sample). In Figure 3, the line with each color represents the distribution (either pdf or cdf) of age for household members in the same rank by age given household size in the same category (from one to six). We can see a relatively clear lifecycle pictures for various cases with different household sizes. For example, households with two members (Figure 3-a2), appear to be dominated by couples as the density curve with a different peaks are quite symmetric in general. The cases for households with five and six members seem a bit more complicated. But for households with six members, the oldest person (black curve in Figure 3-a6) on average is older than that for households with five members. It seems that two mid-aged adults, with one young adult and two kids are the potential dominate household types for households with five members.

![Figure 3 Age distribution of household members by size of households—with different colors representing the rank of the household member by age. Notes: (a1) to (a6) are the estimated probability density function (pdf) plots for households with 1 to 6 members, respectively; and (b1) to (b6) are the estimated cumulative distribution function (cdf) plots for households with 1 to 6 members, respectively.](image)

### Household Mobility Profiles in Singapore

Based on the method described previously, we clustered household mobility profiles in Singapore, and Figure 4 is a demonstration of the clustering results for household with size of three (Figure 4-a1 to Figure 4-a3) and with size of four (Figure 4-b1 to Figure 4-b3) respectively. In Figure 4, there are 11 major columns that count for the mode of a trip, including

1. Cycle,
2. Buses: Public Bus/Company bus/School bus/Shuttle bus,
3. MRT or LRT,
4. Taxi,
5. Motorcycle rider,
6. Motorcycle passenger,
7. Van/lorry driver,
8. Van/lorry passenger,
9. Car driver,
10. Car passenger,
11. Walk and others.

Within each major column, there
are five sub categories with index 1 to 5, represents the travel purpose of (1) go to work, (2) go to school, (3) return home, (4) non work trip, and (5) picking up or doping off someone.

Figure 4 Household Mobility Profiles. Noes: (a1) to (a3) with household size of 3, and (b1) to (b3) with household size of 4.

From the analysis results we find that there are three types of household’s mobility profiles for households with a size of three: (a1) households with equal amount of travel involve modes of bus, MRT/LRT, or walk for work and return home trips, (a2) households with more usage of buses and MRT, for work and return home trips, and (a3) households with dominate use of car, for car driver to go to work, return home and pick up/drop off household members, and car passengers to go to school, and a relative high use of buses for another household member to return home. For households with a size of four, the three types of mobility profiles are quite similar to those for households with a size of car, except that there are increasingly use of car travel for both type 1 and type 2 households, for only go to work and return home trips by one of the household members.

Household Activity Profiles in Singapore

Based on the K-means clustering via PCA method developed by Jiang et al. as described in the Measurement Method subsection in Household Activity Profile section, we first cluster individuals’ daily temporal activity patterns into eight clusters. According to Dunn's Index (DI), which maximizes inter-cluster distances while minimizing the intra-cluster distances, our analysis shows that with a clustering number of 3, it provides the most stable partition of individuals, however the clustering results will only segment individuals into “work”, “school”, and “other” daily temporal activities. With a cluster size of 8, it gives us the second best results
in terms of the Dunn’s index, yet it leads to more intuitive and richer segmentations of individuals’ daily temporal activity patterns, which we call as individual activity profiles.

Figure 5 summaries the cluster results of individuals’ activity profiles in Singapore. The first column of Figure 5 displays individuals’ daily activity sequences for each cluster. The second column shows the aggregated volume of different types of activities in the metropolitan area during a specific time interval over 24 hours. The results contains 8 types of personal activity patterns, including early-bird workers (11.40%), regular workers (27.40%), late and long hour workers (10.80%), the stay-at-home (16.9%), the morning students (15.70%), the afternoon students (4.00%) and the adventurers (4.70%).

Figure 5 Clustering of individuals’ representative weekday activity patterns in Singapore, with clusters (c#1) full-day students, (c#2) adventurers, (c#3) early-bird workers, (c#4) morning students, (c#5) afternoon students, (c#6) regular workers, (c#7) early-bird workers, (c#8) stay-at-home.

Figure 6 Household Activity Profile Clustering in Singapore. Note (a1) to (a5) are clusters derived from households with size of three; (b1) to (b9) are clusters derived from households with size of four. Each column represents the cluster # in Figure 7, and the last column shows the number of household members younger than 4 years old, as the individual activity profile clustering excluded those household members. After getting individuals’ activity profiles, we summarize the number of household members belong to which of the eight categories, and conduct another round of k-means clustering on the households. Figure 6 shows the clustering results of household activity profiles for households with size of three (Figure 6-a1 to Figure 6-a5), and for households with size of four (Figure 6-b1 to Figure 6-b9). Based on the best Dunn’s index as described previously, we found that for household size of three, the best number of clusters is five, and for household size of four, the best clustering number if nine.
Figure 7 Clustering of households’ mobility profiles with household size of three (a1)-(a5) and with household size of four (b1)–(b9).

From the clustering analysis results, we can see that the dominated household activity profiles for household with three members are as follows. (a1) Households with at least one member who works for late/long-hours, and the rest household members have high probability of being either fulltime student, regular worker, or early-bird worker. (a2) Households with at least one member who work for regular hours, and with a high probability of having one type of students or kid younger than four years old. (a3) Households with at least one member who stays at home most of the day, and the rest household members have high probabilities of being either student(s), regular or late/long hour worker, or young kids. (a4) Households with at least one member who goes to work in very early morning and the rest household members have high probability of being either regular worker, stay-at-home. (a5) Households with at least one member who goes out to explore non-work “adventures”, and the rest household members have high probability of being either student, regular worker, or stay-at-home.

The dominated household activity profiles for households with four members have some similarities with households with three members. For example, (b1) type of household can be similar to (a1), but can with a high probability of having an additional stay-at-home person; (b2) type of household can be similar to (a2); (b4) can be similar to (a3); (b6) can be similar to (a4). The rest types of households were quite different. For example, (b3) type of households have at least one full time students, and with high probability of having regular workers, early-bird workers, or stay-at-homes. (b8) type of households is definitely with young kids less than four years old, and very high probability of having a regular worker. (b9) type of households have at least one morning students, and high probability of having regular workers and stay at homes.
CONCLUSION AND DISCUSSION

This paper argues that household lifestyle as the fundamental value and attitudes drive the package of household long-term choice decision making, which include the residential location choice, vehicle ownership choice, and household mobility and activity profile choices. The latter two aspects are newly raised by this paper, because we argue that both household mobility profile or activity profile choices are intertwined with the other two household choices on location, and vehicle ownership, as households are choosing a way of living, working, playing and traveling, when they decide on where to live and whether to own a car in their long-term decision making process. Being able to cluster households based on their mobility profiles and activity profiles will help us understand the potential constraints that a household may have in terms of what other members in the household may do during a typical day, and what modes maybe available to them. This has huge potential in counting for the limitations a household may face in their decision making on household residence choices, vehicle ownership choices, as well as potential travel planning in medium-term daily based decisions. Accounting for household long-term decision on mobility profile, and activity profile influenced by household lifestyles will enables urban planning to plan more sustainable neighborhoods, that accommodating households lifestyle tastes, and allow the room to make policies that targeting the different segmentations of the households.

ACKNOWLEDGEMENTS

This research was funded in part by the MIT Department of Urban Studies and Planning, by the US Department of Transportation Region One University Transportation Center, and by the Singapore National Research Foundation (NRF) through the Singapore-MIT Alliance for Research and Technology (SMART) Center for Future Mobility (FM).

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