Exploring Activity-Travel Patterns in Xiamen, China

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Abstract

Recent research in travel demand modeling has increasingly focused on the analysis of activity-travel patterns and time use behavior. Such activity-based travel behavior research that explicitly considers time use behavior is rarely conducted in developing countries such as China where traffic congestion continues to increase and large investments in multimodal facilities are being made. In this context, it is critical to study and understand traveler behavior in China from the activity-based perspective. The focus of this paper is to present a comprehensive exploratory analysis of activity-travel patterns and trip chaining patterns based on data derived from a household travel survey conducted in Xiamen, China in 2003. The analysis includes an examination of trip rates, trip chaining behavior, time-of-day distribution of trip departure, and activity and travel time expenditures. In addition, the paper includes a comparison of travel behavior between this Chinese dataset and a U.S. dataset collected in the Tampa Bay area of the State of Florida.

Keywords travel behavior, trip-based travel demand model, activity-based travel demand model, trip chaining patterns, time use patterns

1. Introduction

In recent years, the activity-based approach has been increasingly adopted for travel demand analysis and travel demand modeling in place of the conventional trip-based approach. The reasons for this shift in modeling paradigm can be explained from both theoretical and practical perspectives.

Theoretically, travel is undertaken to participate in activities that are scheduled at various times and located at various places. Thus, travel demand is often regarded as a derived demand. The activity-based approach directly models people's activity participation behavior and then derives the resulting travel demand, thereby overcoming the limitations of trip-based approaches which disregard the interactions and constraints that govern participation in activities and travel. Within the context of a travelers' daily activity-travel patterns, trips and activities made by the same individual or

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individuals within a household should be mutually interactive and co-dependent. The activity-based approach can accommodate such relationships by modeling individual activity-travel patterns in their entirety, while the trip-based approach only models trips separately regardless of the relationships among them.

From a practical perspective, activity-based travel demand models offer a stronger behavioral basis than trip-based models for evaluating investments and policies aimed at improving transportation system efficiency. In both trip-based and activity-based models, input variables include individual demographic and socio-economic characteristics, land use characteristics, network level-of-service variables, and Travel Demand Management (TDM) policy indicators such as congestion or value pricing, parking pricing, flexible work hours, telecommuting, and high-occupancy vehicle (HOV) only lanes. The output of a trip-based model is based purely on an analysis of trips treated independently of one another, whereas the output of an activity-based model is based on an analysis of overall daily activity patterns. The analysis of the change in people's daily activity patterns in response to travel management policies offers a behaviorally robust framework for evaluating transport policies as one can identify primary, secondary, and tertiary impacts on travel behavior. Trip-based models may erroneously provide a consistently positive evaluation of policies aimed at suppressing trip-making. For example, the policy of flexible work schedules may alleviate peak-period travel demand but potentially influence other aspects of the overall daily activity-travel pattern that affect people's quality of life. Regardless of the potential net effect of the policy, a trip-based model may always positively evaluate this type of policy due to the shifting of peak period commute trips without giving due regard to secondary and tertiary impacts such as induced travel demand. Activity-based models can evaluate such policies in a more comprehensive framework due to their ability to predict changes in people's overall daily activity-travel patterns in response to policy variables. Measuring the changes in overally daily activity-travel patterns offers a more complete reflection of the impact of the transport policy on people's lifestyles.

As the most populous country in the world, China is being confronted with serious challenges in transportation to meet the requirement of rapid economic development. In the past few decades, China has been investing heavily in new transportation infrastructure in the larger coastal cities, thus laying the framework for an advanced transportation network in these areas. As traffic congestion continues to increase and investments in multimodal facilities grow, there is a need to model transportation systems using new paradigms of traveler behavior for policy evaluation and investment assessment. In this context, it is critical to study and understand traveler behavior in China from the activity-based perspective. The intent of this paper is to analyze travel behavior of people in Xiamen, Fujian, China in terms of activity-travel patterns, trip chaining patterns and time-of-day distribution of trip departure and then to compare these aspects of behavior with a survey sample drawn from Tampa, Florida, USA. Such a comparison would shed light on similarities and differences in travel behavior between developing and developed countries.

Table 1. Household Characteristics of Xiamen Survey Sample (N = 11045)

Household Size	Family Type (N=9082)	Dorm Type (N=1927)
Average	3.89	4.86
1	2.5%	11.15%
2	9.55%	19.06%
3	33.53%	16.30%
4	29.34%	15.32%
5+	25.02%	38.17%
Total	100.00%	100.00%

Monthly Household Income	Percent
Unknown	1.87%
0 Yuan*	3.59%
1~800Yuan	16.73%
801~2000 Yuan	41.61%
2000 ~5000 Yuan	29.13%
5001~10000 Yuan	5.34%
>10001 Yuan	1.71%
Total	100.00%

Plan to buy a car?	Percent
Yes, <= 2 years	5.12%
Yes, 3 ~ 5 years	6.72%
Yes, > 5 years	15.13%
No	73.03%
Total	100.00%

Vehicle Ownership	Bicycle	Motorcycle	Private Car	Public Car
Mean	0.91	0.51	0.09	0.11
0	45.50%	63.94%	92.53%	94.77%
1	31.40%	25.40%	6.55%	3.70%
2	15.88%	8.27%	0.69%	0.63%
3+	7.22%	2.39%	0.23%	0.90%
Total	100.00%	100.00%	100.00%	100.00%

* Yuan: Unit of RMB, currency in China; 1 Yuan = approx US$ 0.123.

2. Datasets and Data Preparation

The dataset used for the analysis of travel behavior in Xiamen is extracted from a household travel survey conducted by Tongji University and Xiamen University in 2003. The population of Xiamen is around 2.14 million including permanent residents (64%) and temporary residents (36%). The sample was randomly selected and a one-day travel diary was completed through face-to-face interviews resulting in a response rate above 95%. After extensive checking and data integrity screening, the dataset used for analysis consisted of 25291 trips reported by 11131 persons from 11045 households. The Tampa Bay data is derived from a household travel survey that was administered in 1996 in the Tampa Bay Region of Florida. The survey was a mail-out, mail-back survey in which a one-day trip diary was filled out by respondents. After extensive checking and data integrity screening, a final respondent sample of 5261 households was obtained. From these 5261 households, a total of 9066 persons returned usable trip diaries. The 9066 persons reported information for a total of 31459 trips. Both surveys constitute traditional trip diary surveys, from which basic out-of-home activity engagement information can be derived.

Tables 1 and illustrate household characteristics and person characteristics of Xiamen sample. Due to space limitations, characteristics of the Tampa survey sample are not included in this paper. As shown in the tables, household size is calculated by family type and dorm type. Average family-type household size is 3.89 and average dorm-type household size is 4.86. Less than two percent of the observations in the Xiamen sample have missing household income information. In the Tampa dataset,

around 30 percent of the observations have missing income information, possibly due to the administration of the survey through the mail and the sensitivity associated with revealing income information. On average, there is nearly one bicycle per household, one motorcycle for every two households, one private car for every 10 households, and one employer-provided public car for every 10 households. More than 90 percent of the households do not own a car, either private or public. A little more than 10 percent of the households plan to acquire a car within the next five years. Nearly three-quarters of the households indicate having no plans to acquire a car. The analysis indicates that auto ownership in China is much less than that in the USA where there is, on average, one automobile per licensed driver. However, auto ownership in China is expected to rapidly increase and place enormous demands for transport infrastructure capacity and traffic management strategies in the future.

Table 2. Person Characteristics (N = 11131)

Gender	Percent	License Status	Percent
Male	58.50%	Licensed	11.49%
Female	41.30%	Not Licensed	88.51%
Missing	0.20%	Total	100.00%
Total	100.00%		
Age Group	**Percent**		
0 - 19 years old	27.27%		
20 - 39 years old	45.74%		
40 - 59 years old	20.50%		
60 - 79 years old	6.10%		
> 80 years old	0.16%		
Unknown	0.22%		
Total	100.00%		

3. Comparative Analysis

Table 3 provides a comparison of trip chaining patterns between Xiamen and Tampa. Trip chaining patterns are initially classified into three broad types: work tour (the tour departing from home, going to work place at least once and coming back home), non-work tour (the tour departing from home, visiting one or more non-work places and coming back home), and incomplete tour (tour departing from home but does not come back home finally on survey day). The term “tour” is considered synonymous to “trip chain” in this paper. Based on the number of stops, non-work tours are further classified as simple non-work-tours (non-work-tour visiting only one non-work place) and complex non-work-tours (non-work-tour visiting multiple non-work places). The sequence and occurrence of non-work trips within a work tour provides a basis for further classifying work-tours into simple work tours (work tour without visiting any non-work places), complex to work tours (work tour only visiting non-work places before initial work trip), complex from work tours (work tour only visiting non-work places after last work trip), complex at work tours (work tour only visiting non-work places between the initial work trip and the last work trip) and other complex work tours (all other work tour). Thus, a total of eight types of trip chaining patterns are defined as shown in Table 3.

Table 3. Trip Chain Type Distributions in Xiamen and Tampa

Trip Chain Type	Trip Chain Classification	Xiamen	Tampa
h-w-h	Simple work tour	26.86%	21.22%
h-(nw)-w-h	Complex to work tour	0.59%	1.34%
h-w-(nw)-w-h	Complex at work tour	1.47%	2.69%
h-w-(nw)-h	Complex from work tour	2.01%	4.80%
h-(nw)-w-(nw)-w-(nw)-h	Other complex work tour	0.63%	3.25%
h-nw-h	Simple non-work tour	45.29%	38.12%
h-(nw)-h	Complex non-work tour	3.96%	15.14%
h-(w)-(nw)	Incomplete tour	19.19%	13.44%
Total		100.00%	100.00%
Sample Size		11800	13099

h: home, w: work trip, nw: non-work trip,
(w/nw): may be absent or present repeatedly, but the tour with (w/nw) is complex in nature.

Table 3 indicates that trip chaining patterns differ dramatically between two areas. Generally, trip chaining patterns in Tampa are much more complex than in Xiamen. The most striking difference lies in the complex non-work tours (about 4% in Xiamen vs. 15% in Tampa). It is found that only 15% of work tours in Xiamen are complex, whereas 36% of work tours are complex in Tampa. Similarly, only 8% of non-work tours are complex in Xiamen, but 28% of non-work tours in Tampa are complex. Potentially, the substantially different levels of car ownership in these two areas contribute to these dramatic differences. In the Tampa Bay area, over 95% of households own at least one private car, whereas, in Xiamen, only around 10% of households have a private or public car. It has been shown that complex trip chaining is strongly associated with auto ownership and usage (Ye et al., 2004).

Table 4 provides average daily activity-travel time expenditures and trip rates for commuters, students and non-commuters in Xiamen and Tampa. Commuters are defined as those who report at least one work trip while students are those who report at least one school trip, but do not report any work trips. The remainder are non-commuters who do not make any work or school trips. The t-test is employed to statistically compare the mean values between each pair of cells in the table. Except for the figures shown in bold, all mean values are significantly different between the two geographic areas at a 0.05 significance level.

On average, workers in Xiamen spend 8 hr 21 min at work while those in Tampa spend about 8 hrs at work. A possible explanation for this difference is that Xiamen workers are more likely to have lunch at the work place than Tampa workers. As work activity durations are derived from work trip records, the midday lunch activity will be absorbed into the work activity duration if no lunch trip is made.

Business is not designated as a trip purpose in the Tampa survey; thus, the business activity is absorbed into “other activities” in the Tampa sample analysis. There is no statistical difference between the home-stay duration for commuters in Xiamen and Tampa. In both areas, commuters stay at home for, on average, 13 hours. Deducting 8 hours for a regular work schedule, it is found that commuters in both areas have about 3 hours for travel and out-of-home activities. Xiamen commuters spend 1 hr 14 min for travel, out of which 32 minutes is for commuting to work. Thus, Xiamen commuters spend an average of 42 minutes for non-work-related travel. Tampa commuters spend 1 hr 35 min for total daily travel, of which 38 minutes is for commuting to work. Thus, the total time spent traveling to non-work activities is, on average, about 57 minutes,

which is nearly 35% higher than that for Xiamen commuters. Despite the difference in travel time expenditure (for non-work trips), it is interesting to note that both Xiamen and Tampa commuters spend nearly the same amount of time, about 85 min, for out-of-home non-work activities (non-work activities at work place are not included). A comparison of the trip rates between the two survey samples suggests that Xiamen commuters participate in fewer, but longer, non-work activities than their Tampa counterparts, thus resulting in a lower non-work travel time expenditure, but an equivalent non-work activity time expenditure.

Table 4. Activity-Travel Pattern in Xiamen and Tampa

	Commuter		Student		Non-Commuter	
	Xiamen	Tampa	Xiamen	Tampa	Xiamen	Tampa
Sample Size	3348	3856	1851	956	5024	4252
Average Daily Activity Time by Various Type						
Work	08:21	08:01	00:00	00:00	00:00	00:00
School	00:10	00:15	08:40	05:51	00:00	00:00
Shopping	00:20	00:23	00:10	00:24	00:43	01:56
Recreation	00:13	00:22	00:06	00:40	00:24	01:36
Business	00:16	NA	00:02	NA	00:24	NA
Daily Care	00:11	00:02	**00:07**	**00:08**	00:28	00:09
Home-Stay	**13:01**	**12:58**	13:18	15:14	20:36	17:18
Other Activities	00:14	00:24	**00:22**	**00:27**	00:50	01:31
Average Daily Travel Time for Various Types of Activities						
Work	00:32	00:38	00:00	00:00	00:00	00:00
School	00:01	00:03	00:38	00:25	00:00	00:00
Shopping	00:04	00:08	00:02	00:07	00:06	00:21
Recreation	00:02	00:06	00:01	00:07	00:03	00:15
Business	00:02	NA	00:00	NA	00:03	NA
Daily Care	00:02	00:01	00:01	00:01	00:03	00:01
Back Home	00:29	00:33	00:34	00:30	00:14	00:35
Other Activities	00:02	00:07	00:02	00:06	00:06	00:18
Total Travel Time	01:14	01:35	**01:17**	**01:17**	00:36	01:29
Total Daily Time	24:00	24:00	24:00	24:00	24:00	24:00
Average Daily Trip Frequency for Various Types of Activities						
Work	1.34	1.38	0.00	0.00	0.00	0.00
School	0.04	0.13	1.48	1.23	0.00	0.00
Shopping	0.16	0.38	0.06	0.39	0.26	0.86
Recreation	0.09	0.23	0.03	0.37	0.11	0.48
Business	0.09	NA	0.01	NA	0.10	NA
Daily Care	0.10	0.05	0.05	0.08	0.15	0.03
Back Home	1.19	1.28	1.23	1.47	0.53	1.17
Other Activities	0.13	0.28	0.13	0.31	0.27	0.61
Total Trips	3.14	3.72	3.00	3.86	1.42	3.15

On average, Xiamen students stay at school for 8 hr 40 min per day, which is much higher than the average 5 hr 51 min school-stay time reported by Tampa students. There is no significant difference between total daily travel time expenditure (1 hr 17 min) for the students in two areas. However, Xiamen students spend longer periods of time traveling to school (38 min vs. 25 min for the Tampa sample), thus implying that Tampa students, on average, spend about 30% more time traveling to non-school activities than

their Xiamen counterparts. This is consistent with the greater level of out-of-home non-school activity participation rate exhibited by Tampa students (about 2.6 activities vs. 1.5 activities for Xiamen students). Thus, in summary, it is found that Xiamen students, on average, spend more time at school and less time traveling to and participating in non-school activities.

Substantial differences are found in activity-travel patterns for non-commuters between the two samples. Xiamen non-commuters spend an average of 20 hr 36 min at home, which implies that they only allocate about 3 hr 24 min for travel and out-of-home activities. However, Tampa non-commuters stay at home for substantially less time at 17 hr 18 min and thus allocate, on average, 6 hr 42 min for travel and out-of-home activities. This is nearly twice as that for Xiamen non-commuters. Relative to Xiamen non-commuters, Tampa non-commuters spend an additional 53 min traveling and an additional 143 min pursuing out-of-home activities. Tampa non-commuters' average daily trip rate is more than twice that of Xiamen non-commuters. These differences may be attributed to higher levels of household and child-care obligations associated with larger household sizes, lower levels of auto accessibility, and other financial and mobility constraints that may be greater in the Xiamen context. Further research is needed to explain these substantial differences in non-commuter activity-travel patterns between the two geographical and cultural contexts.

Figure 1 compares time-of-day distributions of work trip departure and school trip departure in Xiamen and Tampa. Work trip departure time distributions in both areas show a sharp peak in the 7:00-7:59 AM period. However, only about one-quarter of work trips in Tampa depart in this period as compared to a little more than one-third of work trips in Xiamen departing in this period. Xiamen's school trip departure time distribution shows two peaks, one during 6:00-6:59 AM and another during 1:00-1:59 PM. The latter peak in the Xiamen context reflects return-school trips after lunch activities.

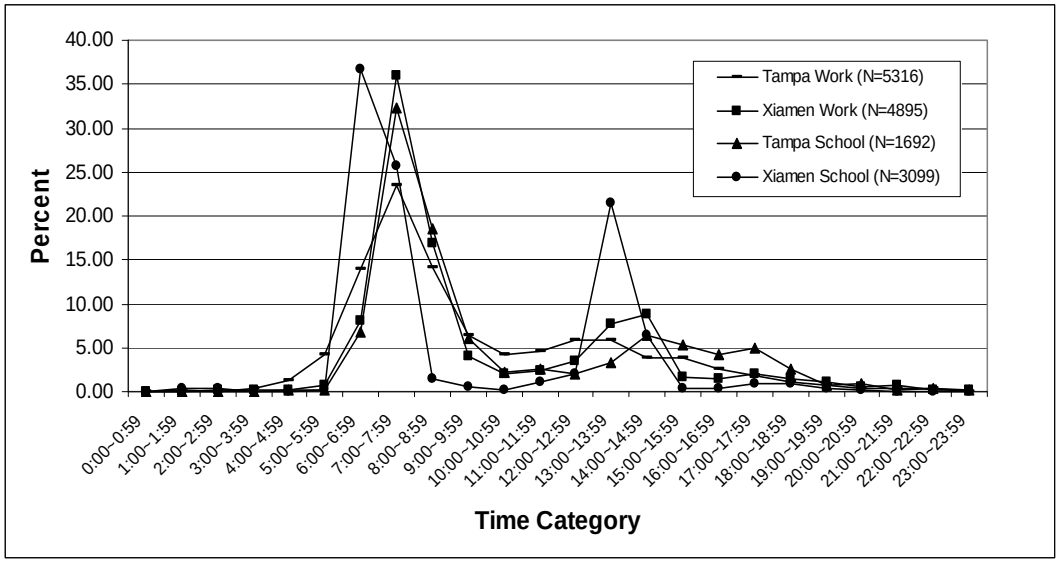

Figure 1. Time-of-Day Distribution of Work and School Trip Departure

The morning peak of school trips in Xiamen is about one hour earlier than the morning peak of work trips. Tampa's school trips, on the other hand, exhibit a peak during 7:00-7:59 AM, which is the same as that for Tampa work trips but is one hour later than Xiamen's school trips. The sharper peaks seen in the Xiamen context suggest that there may be opportunities for peak spreading through travel demand management strategies.

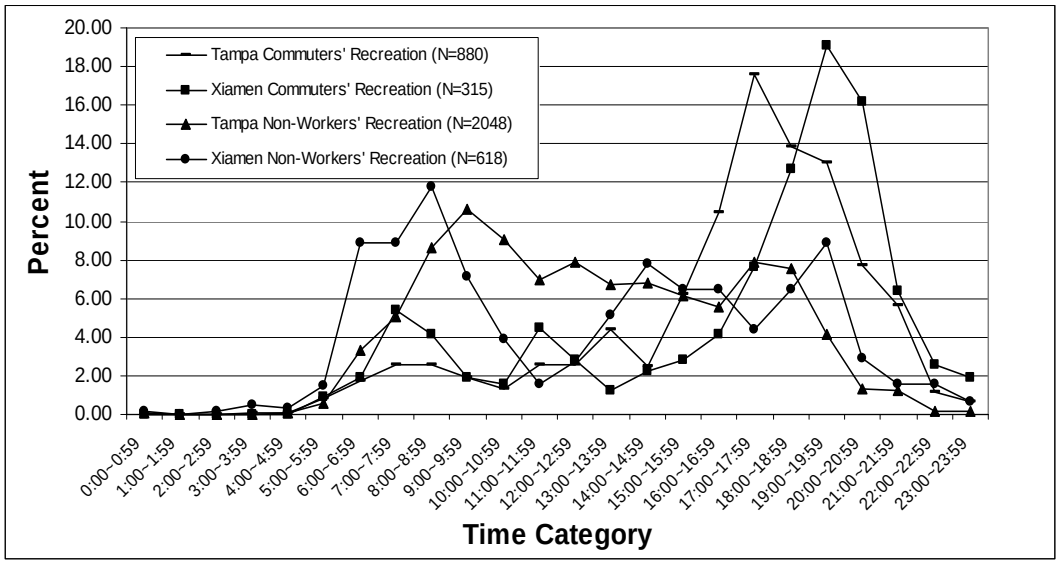

Figure 2. Time-of-Day Distribution of Recreation Trip Departure

Figure 2 compares time-of-day distributions of recreational trip departure by commuters and non-workers (i.e., students and non-commuters) in Xiamen and Tampa. The commuters in both Xiamen and Tampa show a sharp peak for recreational trips after work. Xiamen commuters' recreational trip departure peak appears during 7:00-7:59 PM, which is about two hours later than the Tampa commuters' peak which occurs during 5:00-5:59 PM. Such a difference in recreation trip departure peak is presumably caused by the different lifestyles of workers in the two areas. It is hypothesized that commuters in China are more likely to return home after work and then depart to recreational activities after having dinner and fulfilling other household obligations at home (after work). On the other hand, commuters in the US context may undertake recreational activities on the way home from work (i.e., through trip chaining), thus contributing to recreational trips occurring close to the work-end time of 5:00 PM. Future research should aim to explore and test lifestyle hypotheses of this nature. It is also found that time-of-day distributions of recreational trips differ greatly between non-workers in the two areas. The non-workers in Xiamen show a peak in the morning during 8:00-8:59 AM and a secondary peak during 7:00-7:59 PM, possibly associated with the commuters' peak in the same time period (i.e., joint activity engagement). The non-workers in Tampa show a flatter peak in the morning during 9:00-9:59 AM and then a rather uniform distribution of recreational trip departures throughout the day, with a sharp drop after 8:00 PM.

Figure 3 shows time-of-day distributions for shopping trip departures for commuters and non-workers (i.e., non-commuters and students) in the Xiamen and Tampa survey samples. Commuters in the both areas show peaks for shopping trips

after work. Tampa commuters show a sharper peak that immediately follows the traditional work day, whereas Xiamen commuters exhit a flatter peak over a four hour period of 5:00-8:59 PM. Once again, this difference may be partially attributed to a greater trip chaining (associated with return from work) propensity in Tampa and a greater inclination for Xiamen commuters to pursue shopping activities after dinner at home. Tampa non-workers show a sharp peak during the late morning hour of 10:00-10:59 AM and a flat secondary peak during 1:00-1:59 PM, possibly associated with eating lunch outside home. Xiamen non-workers show only one sharp peak early in the morning at 8:00-8:59 AM, which is about two hours earlier than that of their Tampa counterparts. One plausible explanation might be that non-workers in the US context avoid the morning peak period due to their high level of auto dependence. Another possible explanation is that China's urban residents visit the market early in the morning to shop for daily groceries as part of a habitual lifestyle.

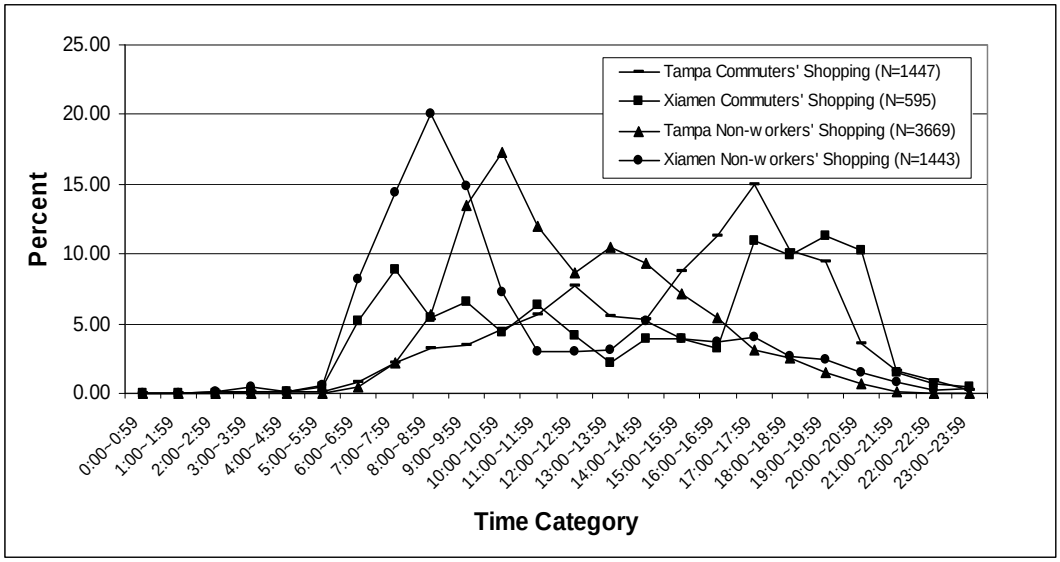

Figure 3. Time-of-Day Distribution of Shopping Trip Departure

4. Conclusions and Discussions

This paper provides a descriptive analysis of activity-travel patterns, trip chaining patterns and time-of-day distributions of trip departures for China using survey data from Xiamen. In addition, the paper provides a preliminary comparison with activity-travel patterns for a US survey sample drawn from Tampa, Florida. The comparisons reveal interesting differences between the two cultural and geographic contexts with greater similarities between commuter samples and greater differences between student and non-commuter samples. Presumably, the traditional 8 hour work day constraint imposes a greater degree of similarity between the activity-travel patterns of commuters. Non-commuters and students in the China context are seen to have lower levels of mobility, particularly for flexible and discretionary activities. In addition, multi-stop trip chaining patterns are found to be more prevalent in the US context, presumably due to the high level of auto ownership and usage that allows such multi-stop trip chains. Comparisons of departure time distributions for different trip types also revealed differences that may be attributable to key lifestyle and cultural

differences. Future research efforts should focus on testing some of the hypotheses regarding lifestyle factors that have been postulated in this paper.

The exploratory analysis in this paper constitutes a first step in understanding travel behavior characteristics in a Chinese urban area. The comparison with the US context helps identify both similarities and differences that exist in activity-travel patterns between the two areas. While the activity-based paradigm provides a common framework for analyzing travel demand in a multitude of contexts, model specifications must be developed to reflect differences across areas attributable to such factors as socio-economic status, vehicle ownership, family structure, urban structure, population density, level-of-service of network, tradition and culture, social values, and political system. There is undoubtedly much scope for future study to explore the underlying behavioral processes accounting for differences and similarities in behavior across contexts.

It is believed that activity-based models are more spatially transferable than trip-based models because activity-based models are more reflective of the fundamental motivation for travel. In recent years, developed countries such as USA (Kitamura et al., 2000, Bhat et al., 2004 and Pendyala et al., 2005), Canada (Miller, 2003), Netherlands (Arentze and Timmermans, 2000), and Switzerland (Axhausen and Garling, 1992), have invested in the development of activity-based models. There is a move to transition activity-based approaches to practice in many of these contexts. The analysis and comparisons presented in this paper will help inform the structure and specification of activity-based travel demand models that may be developed for China in the future.

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