Dynamic diurnal social taxonomy of urban environments

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Abstract
In this paper, we explore how the nature of places changes by time of day due to the collective impact of the social, temporal and spatial dimensions of activity decisions. We focus on how social contexts impact the temporal and spatial decisions of activities by activity types and compare the transition of spatial patterns over time of day. We use very detailed social interaction information in the CentreSIM dataset, which is a household-based activity diary survey collected in Centre County, Pennsylvania, USA in 2003. We offer a methodology to extract the dynamic social taxonomy of places from behavioral data, and suggest how urban and transportation models can be informed from the dynamics of places by observing "what is taking place" combined with "what exists" or "what is available". The results can also be used to improve design of urban environments, temporal planning of places, transportation policies that are sensitive to time of day, and modeling of spatio-temporal decisions of social activities in travel demand models.

Keywords
Social interaction, spatio-temporal analysis, location choice for social activities, dynamic place characteristics, social taxonomy of urban environments

Preferred Citation
1. **Introduction**

Urban environments transform in cyclical manner attracting different activities by time of day. In response to the changing environments, individuals choose to populate certain places that satisfy their need to pursue certain activities at specific times in a day, and they engage in activities alone or with other people creating another factor in the urban diurnal dynamics. Forty years ago, these behavioral dynamics were discussed as one of the important dynamic aspects of urban environments in "what time is this place?" (Lynch 1972).

A quote from this book (Lynch 1972, page 72) explains what we explore in this paper very well:

> Until recently environmental design was preoccupied with the permanent physical artifacts: buildings, roads, and land. But human activities occurring among those artifacts are of equal or greater importance to the quality of a place. With this principle in mind, physical design has been broadened to become spatial design planning the form of behavior and things in space. But if it is to deal with behavior, it must consider the temporal as well as the spatial design, and it becomes an art of managing the changing form of objects and the standing patterns of human activity in space and time together.

This dynamic behavioral facet and its spatial aspects also stress the importance of synchronization of planning and behavior. It is also a major focus of Chapin’s analysis (1974), and received attention as early as the first georeferenced time-use study in Halifax was made available (Janelle & Goodchild, 1983, Goodchild et al. 1993). In this paper we attempt to capture the dynamics of activities focusing on social interaction taking place at different time of day. From the perspectives of transportation and transport geography, the daily dynamics of a place are represented mostly as variability of available opportunities by considering opening and closing hours of businesses (Weber & Kwan 2002, Kim & Kwan 2003, Chen et al. 2011, Yoon et al. forthcoming) and these models focus on what exists and what is available at a place at certain time points. In this paper, we focus more on the temporal patterns of activities taking place to describe the dynamic change of a place especially related to social interaction, which cannot be accounted for by types and availability of opportunities offered at a place but needs the added information of social networks (for definition see Carrasco & Miller 2006) that accessed each location and time of day.

2. **Data used**

We use the CentreSIM dataset, which is a household-based activity diary survey collected in Centre County, Pennsylvania, USA in 2003. Each person in the household provided a 2-day complete record of the activities including detailed information on with whom and for whom the activities were pursued. After data cleaning and verification 1,471 persons (from 718 households) were selected for the analysis in this paper (more details of the dataset can be found in Goulias & Kim 2004).
Respondents were asked with whom they participated in their activities and how many number of people participated in the activities. The persons who joined the activities were classified depending on their relationship with the respondent, and the relationship with the respondent was described using up to five “with whom” variables. Of note, when the respondent participated in an activity, for example, with her husband, and two daughters, their relationship can be coded as “multiple family members” in the first variable with the other four “with whom” variables left null. Out of the total 34,635 activity episodes, the five “with whom” variables have 16,984, 2,447, 425, 64, and 11 not null values respectively. The types of social contacts are listed in Table 1. Among those joint activities, 11,812 episodes were only with family members (9,914 at home activities, 1,818 out of home activities including being at other family member’s place) and 1,092 episodes were only with friends (369 at home activities, 723 out of home activities including being at friend’s place).

Table 1: Social activities with different social groups

<table>
<thead>
<tr>
<th></th>
<th>With whom 1</th>
<th>With whom 2</th>
<th>With whom 3</th>
<th>With whom 4</th>
<th>With whom 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Family</td>
<td>12441</td>
<td>1620</td>
<td>304</td>
<td>33</td>
<td>8</td>
</tr>
<tr>
<td>Friends</td>
<td>1172</td>
<td>215</td>
<td>36</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Roommates</td>
<td>100</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Work-related</td>
<td>1763</td>
<td>156</td>
<td>4</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>School-related</td>
<td>572</td>
<td>113</td>
<td>6</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Other people</td>
<td>760</td>
<td>294</td>
<td>71</td>
<td>21</td>
<td>2</td>
</tr>
<tr>
<td>Pets and animals</td>
<td>176</td>
<td>44</td>
<td>4</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>16984</td>
<td>2447</td>
<td>425</td>
<td>64</td>
<td>11</td>
</tr>
</tbody>
</table>

The activities with family are mostly reported by all the individuals who participated in the activity except for extended family members. For example, when a family of three members had lunch at a restaurant, the activity was reported three times, once by each household member in the survey. However, the activities with friends are reported only once by the respondents and the number of friends who joined the activities is reported as a separate variable.

The spatio-temporal diagrams of Figure 1 show how differently the study area is populated by different types of social interaction at each time in a day. The vertical axis represents time of day starting from midnight at the lowest point, and the colors show the starting time of each activity. For example, the place marked with a square is densely populated with solo activities including work and school activities during the day, becomes a family place from 2pm to 6pm, and transforms into a place for interaction with friends after 8pm and it continues until 2 am (see short activities in red color in Figure 1-C). In addition, the spatial distribution of interaction with family is more dispersed than the spatial distribution of interaction with friends.
In the next sections, we separate in-home and out-of-home social activities with family and with friends and provide spatio-temporal analysis of them.
3. Analysis of within-day temporal patterns

3.1. In-home social activities

Figure 2 shows the temporal distribution of the activities reported in the survey by activity type for activities with family and activities with friends. It includes all seven days of week.

From the temporal distribution of the in-home activities with family, we observe a very clear impact of out-of-home work hours between 8am to 6pm. The number of activities reported is very small during this time period compared to the other times of day, and there is only a small peak of eating activity at lunch time. After the work hours, there is the highest peak of eating activity (green color) at 6pm and an increasing number of activities for watching movies, reading books, and using computer (purple color) until 10pm.

On the other hand, the interaction with friends is not affected by out-of-home work hours as clearly as the interaction with family presumably due to the different characteristics of the persons who reported interaction with family and the persons who reported interaction with friends. The eating activities with friends extend until later hours than the eating activities with family because the eating activity serves different purposes when different social interactions are involved. When it is with family, eating itself is the main purpose. However, when friends are involved in eating, the social interaction becomes more important than intake of food, and the social context dictates the temporal dimension of eating activities. In addition, watching movies, reading books and using computer (purple color), playing, playing games and socializing (blue color) extend until late (2am) when they are with friends due to the social context as well.

These patterns show that even though the activity type is the same, the temporal decisions on the activities become different depending on the social context. The temporal decisions include beginning and ending time, duration, arrival at and departure from home to pursue the in-home social activities. In addition, the interaction with out-of-home activities (i.e., bargaining and compensation in time use, sequencing, etc) will also be different depending on the social context of the in-home social activities for the same activity type.
a) Interaction with family

b) Interaction with friends

Figure 2: Temporal profile of in-home social activities with family and friends
3.2. Out-of-home social activities

In this section, we selected activity types that can directly be associated with specific types of businesses and were reported more than certain number of times in the survey, and analyzed their temporal patterns. One of the activity types selected here are EATING activities including eating meals at restaurants and at fast food restaurants, drinking coffee, eating ice creams and desserts, drinking at bars, which covers all the consumption of food and beverages reported in the survey. The other activity type selected is SHOPPING activities including shopping at grocery stores, convenience stores, office and home supply stores, pharmacies, electronics stores, big retail stores (Walmart, Target, etc), and big malls, and shopping for clothes, shoes and anything to wear as well. However, shopping activity excludes picking up food from restaurants and fast food restaurants.

In Figures 3 and 4, the time-of-day distribution of each activity type with family and with friends is shown. Weekday activities and weekend activities are separated by the colors as well. Comparison between eating activities with family and friends shows that eating with family is very concentrated at regular eating hours (noon to 1pm for lunch and 6pm to 8pm for dinner) and eating with friends is more spread throughout the day. Eating with family on weekends shows similar temporal distribution, but tends to pursued earlier and ends earlier as well than on weekdays, and eating with friends on weekends are pursued more in the evening than for lunch and tends to end earlier than on weekdays as well. Based on these observations, during lunch time in weekends, restaurants in the study area are very likely to be populated more by families than by friends.

On the other hand, shopping shows a clearer peak in the evening when it is with friends during weekdays than when it is with family. During weekends, however, shopping with friends is spread throughout the day and even starts earlier and ends later. Shopping with family during weekdays is spread from 9am to 9pm without very clear peaks, but shows a very clear peak between noon and 3pm during weekends.

The temporal profiles of eating and shopping activities show that these activities are pursued at different times of day depending on which social interaction is involved in the activities. In addition to this exploratory analysis, we are going to include more sophisticated analysis on the timing of these activities in the version that we are going to present at IATBR.
a) Out-of-home eating activities with family

Figure 3: Out-of-home activities with family
a) Out-of-home eating activities with friends

![Graph showing the number of activities reported at different times of the day for weekdays and weekends.]

b) Out-of-home shopping activities with friends

![Graph showing the number of activities reported at different times of the day for weekdays and weekends.]

**Figure 4:** Out-of-home activities with friends
4. Spatio-temporal analysis of out-of-home social activities

In addition to the analyses of temporal dimension of social activities of the previous section, we are developing a methodology that is able to account for spatio-temporal correlation of attractiveness of places for social activities. As shown in the previous sections, the type of social interaction involved is tightly associated with the spatio-temporal decision of the social activities and the association differs across social interaction types. This association, again, makes places to be populated by different social interaction by time of day. From this relationship we can be informed about how a place attracts different social interaction by time of day and how the attraction is spatially and temporally correlated with clustering effects. The methodology we are going to develop is a spatio-temporal interpolation most likely based on spatial statistics, which account for distance-dependent correlation.

As an exploratory analysis of spatio-temporal patterns of social activities in the study area, we present kernel density maps of number of people who participated in social activities multiplied by minutes spent during 2 hr time periods. The kernel density calculates the intensity per unit area using a kernel function to fit a smoothed intensity surface over each point. In this case the points are the activity locations. Conceptually, a smoothed curved surface is fitted over regularly spaced points within a predefined range. The surface value is highest at the location of an observation point and diminishes with increasing distance from the point, reaching a value of zero at the search radius distance. The search radius is called as the bandwidth of the kernel function. Thus, larger kernel bandwidths results in smoother intensity surface. In this case, we wanted to use a bandwidth that corresponds to the spatial correlation of the social activity intensity and tested several different bandwidth settings for the kernel density. Since kernel density does not allow selection of the best parameter settings based on statistical fit indicators, we assumed that the spatial correlation does not extend far more than a few blocks and therefore chose a bandwidth of 500 meters in estimating the kernel density. The kernel function is based on the quadratic kernel function as described in Silverman (1986).

Figures 5 and 6 show the transition of spatial patterns of eating activities with family (Figure 5) and with friends (Figure 6) across twelve 2 hr periods. As described in the previous section, the eating activities with friends extend until late (2am). However, in addition to that, it is possible to observe that the spatial extent of the locations where eating activities with friends are pursued gets constrained within a very small area compared to that of earlier hours. It is presumably due to the businesses that offer opportunities for eating at late hours are clustered within the area. This finding shows the necessity to obtain business opening and closing hours to model the spatio-temporal decision of social activities.

It is also possible to observe that the locations where families visit for eating is more evenly distributed with lower activity intensity (number of people multiplied by minutes spent) than the locations where friends visit for eating.

Another important finding is that places change their nature by time of day and attract different social interaction. The location indicated with a black oval is populated by friends between noon to 2pm and 6pm to 8pm to a certain level, but it is almost completely
family place between 4pm to 6pm and highly dominated by families between 6pm to 8pm. The location indicated with a blue oval, on the other hand, is populated by families until 8pm at a certain level, but dominated by activities with friends between 6pm to 8pm and become place for interaction with friends after 8pm.

Using the methodology we are developing, we are going to account for the temporal correlation as well as the spatial patterns of the attractiveness for social interaction. In that way we can have a more robust behavioral inference from the observations in the survey data.

**Figure 5:** Eating activities with family on weekdays (green: low density, yellow: medium density, red: high density)
5. Summary and conclusions

In this paper a preliminary analysis of social context and spatio-temporal patterns is provided by activity types. We have shown that social context is a very important determinant in spatio-temporal decision making for activities and this collectively contributes to the signature characteristics of places by time of day. From this relationship we can be informed of how places change their nature and attract different social interaction by time of day as well. This relationship stresses the importance to obtain when opportunities are offered by businesses and to compare it with the timing of actual activities depending on social context.

To expand this information from the observations to the entire study area, we analyzed the spatio-temporal patterns of different social activities by place types and are planning to correlate them with spatial variables such as built environment measured as accessibility,
residential density, locational characteristics within the study area and types and mixture of businesses. In this way, we derive the relative attractiveness for different social activities by time of day for the entire study area and develop a dynamic social taxonomy of urban environments in their daily cycle.

Overall, we offer a methodology to extract the dynamic social taxonomy of places from behavioral data and to perform spatio-temporal interpolation, and suggest how urban and transportation models can be informed from the dynamics of places by observing "what is taking place" combined with "what exists" or "what is available". The results can also be used to improve design of urban environments, temporal planning of places, transportation policies that are sensitive to time of day, and modeling of spatio-temporal decisions of social activities in travel demand models.

In this version of our paper, we offered an exploratory analysis, but this will be improved in the next version and most likely will be complete by the time of the IATBR conference presentation. The next version of our paper will be offered as hard copy at the presentation.

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References


Lynch K. (1972). What time is this place. The MIT Press.

