On the Structure of Weekly Activity/Travel Patterns




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## ABSTRACT

Understanding the process of activity scheduling is a critical prerequisite to an understanding changes in travel behavior. To examine this process, a web-based activity survey program, REACT!, was developed to collect household activity scheduling data. REACT! is unique in that it records the evolution of activity schedules from intentions to final outcomes for a multi-day period. This paper summarizes an investigation of the structure of activity/travel patterns based on a REACT! data set from a pilot study conducted in Irvine, California. The term structure refers to the outcome of a set of decisions facing individuals as they conduct their daily activities. At a minimum, structure can be interpreted as the sequence by which various activities enter one's daily activity scheduling process. Results of the empirical analyses show that activities of shorter duration were more likely to be opportunistically inserted in a schedule already anchored by longer duration counterparts. Additionally, analysis of tour structure reveals that many trip-chains were formed opportunistically. Travel time required to reach an activity was also positively related to the scheduling horizon for the activity, with more distant stops being planned earlier than closer locations.

Keywords: Time use, activity and travel patterns, activity scheduling

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## INTRODUCTION

Travel, viewed in theory as derived from the demand for activity participation, has long been practically modeled from a trip-based perspective. Trips, rather than activities, have served as the units of analysis. Despite well-known deficiencies (*1*), this conventional modeling approach continues to be the primary analytical tool for urban transportation planners and policy makers. By the mid-1970s, travel demand researchers had recognized the need for more behavior-oriented models as the conventional approach failed in the evaluation of policies other than those directed toward major infrastructure improvements (*2*). A new analytical framework, generally referred to as the activity-based analysis, has been formulated in response to this discontent with existing models.

The activity-based approach links travel to the fulfillment of the needs for activity participation. Travel is explicitly viewed as a derived demand, in consideration of how a trip is related to a specific activity, and when, where, with whom, and for how long this activity is conducted. Early applications of activity-based models focused on explanation of behavior rather than its prediction, and often these applications were directed toward uncovering empirical evidence on the degree of the conventional approach's fallacies. As such, the activity-based approach was often characterized as fragmented and lacking a unified methodological framework. A profusion of concepts and methods were developed as researchers carved out portions of the problem by forming partial theories or modeling applications based on segments of the entire decision-making process (*3,4*). As researchers began to take much-needed steps toward integrating these approaches, they found their efforts increasingly focused on the decision processes comprising household activity scheduling. The goal of such a comprehensive framework is the prediction of patterns of activity participation and travel.

Although significant advancement has been made in the development of methods and models of household activity/travel patterns (*4*), there remains a significant gap between theory and practice in activity-based approaches. Gärling et al. (*5*) argued that most models are "confined to what factors affect the final choice, whereas the process resulting in this choice is largely left unspecified". Axhausen and Gärling (*6*) stressed the importance of the activity scheduling process by arguing that it is at the core of travel behavior changes. Effects of transportation policies such as tolling, congestion pricing, and travel demand management measures depend on how people would adjust their daily activity and travel pattern to changes in their everyday lives. They also argued that the process is “largely unknown” and new methods should be developed to conduct in-depth study of the process.

Although various theories and models of activity scheduling behavior have been proposed (*7*), most have been directed toward describing revealed behavioral patterns. Data on activities rather than on the scheduling of these activities were used in the formation and validation of these theories. A notable exception is Cullen and Godson (*8*), which involves a unique time budget tailored for the authors’ hypothesis about the structure of individuals’ activity patterns. The term structure refers to a wide range of decisions that detail the ways that people conduct their daily activities. At a minimum, structure can be interpreted as the sequence by which various activities enter one's daily activity scheduling process. Cullen and Godson formulated the renowned activity-peg theory hypothesizing that certain activities in one's daily schedule tend to act as pegs around which the ordering of other activities is arranged and shuffled according to their flexibility. Any periods of time that are left free are either scheduled in a later, shorter planning period, or are ultimately occupied by spur-of-the-moment activities (or simply left unused). Cullen and Godson test their hypotheses using a data set that contains information about the priority and flexibility of activities for 336 respondents drawn from the academic staff and students of a college of London University (as part of a more applied study of university contact and location factors). The instrument was based on a recalled, one-day time budget administered by interviewers on weekdays, but a set of specially designed questions were attached to each activity record.

This paper describes an in-depth investigation of the decision structure resulting in observed activity/travel patterns. A web-based self-administered computerized survey instrument, REACT!, was developed and utilized in a pilot study (*9*) to collect data on household decision making. The data collected contain information similar to those in Cullen and Godson's, such as spatial and temporal structures (i.e., execution time and location), type of participants (i.e., involved persons), and degree of pre-arrangement (i.e., time horizon when the decision of carrying out a particular event was determined). However, the REACT! data set is richer in that it was collected over a week period and respondents were also asked to record advance knowledge of upcoming events. With this data, analyses extending Cullen and Godson's can be pursued. For events other than basic activities (decision timing for in-home meals, personal hygiene, and sleep was not collected), a variable indexing how far ahead in time an event was scheduled was derived from the data. With this scheduling horizon index, the analysis proceeds to investigate the inter-relationship between an activity's scheduling horizon attributes (e.g., duration, location, and involved person). It's expected that this analysis can significantly advance our understanding of the behavioral process beyond the decisions of travel and activity participation.

## REACT! SURVEY DATA

REACT! is a modular software application that automates many aspects of the activity survey process and incorporates an automated household interview and an extensive on-line help facility. Survey respondents execute a REACT! self-install procedure on their own computers and are guided by the program to negotiate the survey. The surveying process is divided into three self-completing data entry stages: initial interview, pre-travel, and post-travel. Fully computerized user interfaces are built for each stage. The Initial Interview is a series of questions designed to collect basic household and personal information. Tracing of the weekly scheduling process is accomplished in the pre-travel and post-travel stages. In the pre-travel stage, initiated on the Sunday evening when survey week begins, respondents are asked to enter activities that they have already planned (to any degree) for the coming week. In the post-travel stage at the end of each survey day, respondents update their executed schedules for the current day and enter new activity plans for the subsequent days. The process of post-travel reporting and plan updating continues until the respondent finishes reporting executed schedules for the last day of the survey week.

Data used in this analysis are derived from a REACT! pilot study in Irvine, California from April to June, 2000. Weekly diaries of 72 adults are included in the analysis. There were 12 single adult households (one with a child), 19 couples without children, and 11 couples with one to two children. The average age of the respondents is 28.54 (the oldest is 55 while the youngest is 20). There are 34 male and 38 female respondents. Although the sample was collected from student communities (i.e., graduate students of the University of California, Irvine), not all of the respondents were students. There were 27 non-student, 10 of whom were employed and 17 not employed. Among the 45 students, 31 of them were employed and 14 were not employed.

## STRUCTURE OF ACTIVITY PATTERNS

According to the activity-peg theory, certain activities tend to act as schedule anchors around which other activities are later organized. It can be hypothesized that short duration events are more likely to be those with shorter planning horizon. For example, they could be left unscheduled before a day began and later opportunistically fitted into a schedule which is already partially arranged with more constraining events (e.g., events with longer durations) as the day evolved. The reasoning behind this hypothesis is that, since the activity requires only a small amount of time to complete, there usually would be several free time windows available for such activities. Individuals can wait for the opportunities when they are free from other engagement. In addition, it could also be that some activities are just naturally spontaneous in a specific time and locations. For example, while at home, it is very natural for someone to turn on television and watch for half an hour without thinking about it. It is reasonable to expect that short events are of this nature, because it is not likely that someone would spontaneously do something for a few hours without being broken by other constraints, unless there is a long, continuous period of free time available (e.g., in the evening or on a weekends). These hypotheses can be tested by directly examining the relationships between characteristics of an activity and the time horizon when the decision of undertaking it was made. To achieve this goal, a variable identifying an activity's scheduling horizon is needed.

### Scheduling Horizon Index

An ordinal variable with four levels, indicating how far in advance the decision of participating in a given activity was made, was computed from the REACT! data:

1. Before the week planning
2. Within week planning
3. Within day planning
4. Spur of the moment

Events labeled as "Before the week planning" are those planned (to some degree) and entered on the beginning Sunday. Such activities were often repeated each week. It is reasonable to treat them as having the most advanced scheduling horizon for these activities had been recognized and structured prior to other events. Events counted as "Within week planning" were those known at least one day before they were performed, but not necessarily as early as the first Sunday. The above two levels correspond to activities that were known at least a day before. When an activity was entered to the program after it was done, REACT! would ask respondents about the short-term decision timing of undertaking this activity. The "Within Day planning" level corresponds to decision timing of "earlier in the day", while the "Spur-of-the-moment" level contains activities scheduled in the nature of "right before the activity", "right after the previous activity", or "during previous activity". Although these two levels of planning were both performed within the same day, the difference is that one is largely spontaneous and the other might have minimal level of planning involved.

It is important to note that the terms "planning horizon" and "scheduling horizon" used in this presentation[*] do not necessarily suggest that people at all time consciously think about when to do each activity. They merely denote the advance horizon at which the occurrence of each activity was known and expected. Underlying the categorization of the planning levels is a continuous variable measuring time interval between an event's first entering the overall scheduling flow and its finally execution. Interpretation of each level should not be strictly based on the literal meanings of its label. For example, "before the week" event is not necessarily planned a week ahead of other events. However, it was earlier than events of other levels.

**Contingency Tables of Scheduling Horizon**

The scheduling horizon variable is used to examine the overall scheduling structure in terms of which activities anchored the schedule and which ones were opportunistically performed. The units of analysis are activities. Because the variables under examination are mostly categorical (e.g., planning levels, type of involved persons, and location in terms of in-home or out-of-home), contingency tables are used to explore the relationship between an activity's planning horizon and its characteristics. Two-way contingency tables are used first to directly examine the overall relationship between an event's scheduling horizon and its attributes. Three-way tables are then used to extend the analysis and ensure that the revealed two-way relationships are not entirely due to either a single factor (e.g., the activity's purpose being work/school). It is noted that sometimes respondents indicated that they did not know or remember the decision timing of certain activities. The scheduling horizons of these activities were labeled as "missing".

[*] The terms "schedule" and "plan" are used interchangeably in this paper. Neither suggests whether an activity was consciously planned or not.

*Two-Way Contingency Tables*

For analytical tractability, individual activities are aggregated to five functional classes. Table 1 lists the activity classes and the corresponding lists of activities. Table 2 tabulates the number of activities (of various functional classes) that fall into each planning category. For each activity class, there are two numbers presented under each planning category. The one on the left is the number of events in that category. On the right is the proportion of events, of the same activity type, planned within this horizon. This proportion is computed by dividing the cell count by the corresponding row sum. The Pearson goodness-of-fit statistics ($\chi^2$) is large enough to reject the null hypothesis that the observed cell counts are the same as those produced by chance (*10*), which essentially indicates that the two factors (activity type vs. planning horizon) in this table are not independent of each other.

Overall, approximately 41 percent of all events were spur-of-the-moment. Together with within-day planning, events entered on the execution days accounted for 47 % of all events. Events known before the execution day (i.e., before-week and within-week) accounted for 45% of all events (i.e., another 8% were missing or unknown). Work/school activities were primarily (43.42%) planned on the first Sunday evening or at least a day prior to being performed (21.02%). It is surprising to see that some work/school events (23.09%) were spontaneous. Note that this functional class includes school activities and school-related events, such as studying, usually happen whenever students have time available. Except for work, most activities were relatively impulsive. However, the overall frequency distribution does not seem to contradict one’s expectation. For example, approximately half of the social events were known before the day (i.e., including before-week and within-week). It is reasonable to expect such distribution, since church and religious events were within this functional class.

Tables 3 shows how planning horizons vary across events with different durations. Events over 180 minutes were separated as a group to show that longer duration events did have higher chance of being planned early, and it was demonstrated that an activity with longer duration was usually had more advanced planning horizon. As the duration of an event increased, the chance for it to be planned before or within the week increased, and that of being spur-of-the-moment decreased. This supports the earlier hypothesis stipulating that events with short duration are more likely to be impulsive.

*Three-Way Contingency Tables*

Comparing to other activity classes, work/school is the only activity type that has a significant higher proportion of structured events than opportunistic events. There is a concern regarding if the patterns observed in the two-way tables would hold, when work/school activities were isolated from the analysis. The same concern is applied to the location factor of being in-home or not, because in-home activities could also be predominantly impulsive. If in-home activities were to be separated from out-of-home activities, would the patterns revealed in the two-way tables be observed in both groups? To answer these questions, three-way contingency tables were used to verify the two-way relationships in the presence of a significant third factor. A dichotomous location or activity type variable (i.e., in-home vs. out-of-home, and work/school vs. non-work/school) is introduced in contingency tables as the third factor.

In a two-way table, there is only one way to describe the relationship: either the rows and columns of the table are associated or they are not. A three-way table offers multiple ways, each referred to as a model, of describing the interrelationship among the three factors:

1. Complete independence: The three factors classified in the table are completely dissociated. The classification of any factor has no effect on the classification of any other factor or combinations of any other two factors.
2. One-factor independence: One of the factors in the table is independent from the other two. Hypothesis testing of one-factor independence can be performed for any one of the three factors.
3. Conditional independence: Two factors in the table are conditionally independent from the third. For example, A is associated with B and B is associated with C, but A and C have no association. In this example, the pair of A and C is said to be conditionally independent from B. Testing of conditional independence also allows for three sub models, with any pair of factors being tested against the third.
4. Homogeneous association: This model hypothesizes that there is a relationship between every pair of factors in the table that does not interact with the remaining factor. Simply put, every two factors of the three are related, but they do not interact all together.
5. Three-way association (Saturated model): A three-way association assumes that every pair of factors interacts with the remaining one. A saturated model has no degree of freedom thus its test statistics are always zero (i.e., the model fits data perfectly). It is the default model with which other models are compared for goodness-of-fit measures (i.e., testing the null hypothesis that the target model is not significantly different from the saturated one).

Hypothesis testing of the three way models are usually accomplished with log-linear models, which hypothesize that the logarithm of the expected frequency of a particular cell is a linear combination of the associated row and column terms. Except for the saturated, each of the above models can be represented as such a linear combination that is subsequently compared to the saturated one (i.e., a perfect fit that in reality does not exist) for goodness-of-fit statistics*.

The following series of tables present the analysis results. Test statistics of all models are summarized on the bottom half of each table. Table 4 summarized the three-way relationship among location, activity class, and planning horizon. Overall, the two-way pattern between activity class and scheduling horizon (see Table 2) can not be observed in the in-home group. Majority of the in-home events were improvised during the day. Only a small portion of in-home work events were recognized at the beginning of the

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* A complete presentation of the formulation of log-linear models requires extensive elaboration and formal mathematical notations. See Wickens (*10*) for such a presentation.

week. Specifically, intention of working at home was mostly formed and realized throughout the week with a high proportion of spontaneity. In-home social events were polarized at either spur-of-the-moment improvisation or before-week planning. Phone calls (over 10 minutes) were the major component of the former, while events like hosting visitors were expected early in the week. In the out-of-home group, the overall frequency distribution resembles the structure of the corresponding two-way table (see Table 3) with the exception that both out-of-home maintenance and recreation events have a slightly higher structural (i.e., within-week and before-week combined) proportion than shopping activities. Out-of-home maintenance events were exclusively pick-up/drop-off passengers. This should explain its high planning proportion. Log-linear analysis of this table indicates that none of the three factors is expected to be independent from the other two. Although no significant model is found, a fitted model is likely one between the homogeneous association and the saturated, which also indicates the highly interrelated bound among the three factors.

The two-way structure of duration and scheduling horizon (see Table 3) is consistent with the pattern shown in the out-of-home group in the corresponding three-way table (Table 5). Out-of-home activities with longer duration do have a higher tendency of being planned early and less chance of being improvised during the day. This pattern is not as distinct for the in-home group. While the proportions of spur-of-the-moment and within-day events did decrease as duration increased, it's the within-week column, rather than the before-week one, that ascends consistently. It can be postulated, based on the findings, that the hypothesized structure between activity duration and planning horizon is also valid for in-home activities, however, the structure operates over a shorter horizon. There is no distinct pattern for longer term planning of in-home events. Test statistics suggested that all three factors are mutually dependent.

The frequency distribution of duration versus planning horizon (Table 6) in the work groups reveals the expected structure (i.e., the longer the duration the earlier the scheduling horizon). In the non-work group, although the structure is not as distinct, the pattern can still be recognized. Events with the longest duration are indeed the least impulsive and the most planned, but the difference between the other two duration categories is marginal. In addition, the before-week proportion of the middle category is slightly less than the shortest one. This suggests that non-work events were mostly improvised during the day. People do not intentionally schedule non-work event unless the duration is of certain length. The homogeneous association formed by the three factors is the most significant model among all.

Intuitively one would assume that "alone" events are the most impulsive, since no other persons would constrain the decisions and action. Table 7 demonstrates that the supposition is indeed a valid one for non-work activities. In the non-work group, the proportion of spur-of-the-moment decreases from top to bottom, which can be considered an increasing order of a coupling constraint. The before-week column does not increase in this order, but within-week does show such tendency. Work events with other people involved mostly long term planning, while working alone showed more flexibility in that spur-of-the-moment events constituted a substantial proportion overall.

## THE STRUCTURE OF TRAVEL PATTERNS

The lack of treatment for multi-sojourn travel (i.e., trip chains) in trip-distribution models has been regarded as one of the most serious drawbacks of the conventional travel demand model. Various theoretical and analytical methods have been proposed to address trip-chaining behavior, and most of these models (*11*, *12*) have relied on utility theory to produce optimum travel patterns as a result of individual utility maximization. The most often cited critique of utility-based models is their strong assumption on an individual's capability of making perfect decisions that optimizes internal utility, usually represented by a function of expenditure for activity participation and travel. When applied to the analysis of trip-chaining behavior, the utility approach is subject to another strong assumption: elements of a trip-chain (tour), such as the number of sojourns (stops), the type of activity at each stop, and sequencing of the stops, are determined simultaneously. Although this assumption results in practical models, its level of deviation from real behavior has never been investigated. In this section, all out-of-home activities are grouped into tours to investigate the mechanism of trip-chain formation. By examining the planning horizon of the event at each stop can help identify if stops in a tour were determined simultaneously or sequentially. If a tour was not determined simultaneously, stops in the later part of a tour may be more likely to be opportunistically determined than the earlier stops. In addition, it is reasonable to expect that if one of the stop in a tour requires a longer travel time, the event occurring at the stop is likely to be considered earlier. Similarly, in a tour a spur-of-the-moment stop is more likely to occur if it is close to the current location.

A tour is composed of a sequence of out-of-home stops (i.e., activity locations). If more than one activity occurred at the same location consecutively, the location is counted as one single stop. Stop sequence increases only when the person went to another location for a different event. A total of 802 tours were identified from all out-of-home activities (excluding for jogging and recreational biking that started and ended at home and did not serve a purposes other than exercise). Table 8 shows the structure of tours in terms of when the event at each stop was planned. Out-of-home meals are also included in the table, since they accounted for a small portion of overall out-of-home activities. The lower portion of the table contains mostly empty cells, since there were very few tours containing more than three stops. The analysis focused on 2-stop and 3-stop tours and the results demonstrated that the proportion of opportunistic stops increased as stop sequence increased. For two-stop tours, approximately 60 percent of the events occurring at the first stop were planned (before-week and within-week), but only 19 percent were determined opportunistically (i.e., spur and within-day combined). The planned and opportunistic proportions are almost identical at the second stop. Among three-stop tours, the cell counts of the first two stops are similar to those of the two-stop tours. However, at the second and third stop, the opportunistic portions are higher than the planned. Hypothesis testing of independence was performed separately for two and three stop tours only, since there are not enough records of tours with more than three stops. The testing results verify that the relationship between stop sequence and scheduling horizon is not due to chance (i.e., the hypothesis of independence is rejected).

Based on the above findings, it can be inferred that the decisions of visiting stops in tours are not necessarily simultaneously pre-determined, although there are definitely a number of tours that are opportunistically formed. While engaging in planned activities, individuals may see opportunities of completing certain activities at different locations later in the day. The decision of undertaking these activities or not would be based on the (not necessarily conscious) evaluation of feasibility. It is reasonable to expect that travel time required to reach the activity locations would be considered as an evaluation criterion. For example, a spur-of-the-moment event is likely to occur if it is close to one's current position. Table 9 shows the three-way cross table of event type (work/non-work), travel time to reach the event location, and the event's planning horizon. The spur-of-the-moment proportion clearly descended as travel time increased in both groups. Within work group, the proportion of before-week also increases in this order. Attention should also be directed to the within-day column. Proportion on this column increase as travel time increases in both groups. This suggests that if one spontaneously comes up with the idea of doing something, it might be undertaken immediately if the location is very close. If the location was distant, the chance is greater for it to be scheduled later in the day. Test statistics indicate that observed relationships are valid, since no independence between duration and scheduling horizon can be concluded. Consistent with conventional wisdom, the conditional independence between work and travel time is significant, indicating the weak association between them.

## SUMMARIES AND CONCLUSIONS

Data collected with REACT! were used to examine the structure of activity and travel patterns. The series of analyses validated that the "activity-peg" phenomenon does exist. Two-way contingency tables show that activities with shorter duration were more likely to be opportunistically filled in a schedule already anchored by their longer duration counterparts. Dichotomous location and activity type variable (i.e., in-home vs. out-of-home, and work/school vs. non-work/school) are each included in three-way contingency tables as the third factor to verify the two-way relationships in the presence of a third factor. In general, results of the three-way tables supported the contention that the structures revealed in two-way tables are still valid in the presence of the third factor. The analyses of tour structure show that the proportion of opportunistic stops increased as stop sequence increased, but the proportion decreased as travel time increased. Overall, these results demonstrate that a certain portion of trip-chains was opportunistically formed, rather than the simultaneous chaining suggested by conventional models.

The analysis presented here points out two potential directions to improve practical travel demand models. First, in terms of data collection, the conventional activity/travel diary approach needs to be augmented. It is found that a certain portion of out-of-home activities actually occurred spontaneously. Thus, taking "snapshots" of the revealed activity patterns for a day or two does not necessarily capture consistent patterns. Asking questions related to individuals' typical activity program seems to be a way of addressing this dilemma. For example, based on the finding that individuals tend to adjust timing of events rather than the locations, it may be worthwhile to consider adding questions to conventional travel diaries addressing whether there are frequently visited locations. If the set of alternative activity locations were known, it would improve the chances to deduce the decision strategies that resulted in the revealed patterns. Second, this analysis clearly demonstrated that the behavioral strategy behind everyday activity scheduling is close to the viewpoint of transactional opportunistic (i.e., the activity-peg theory) rather than a simultaneous utility-maximization. Instead of contemplating the optimal choices before action, individuals are often improvising in an environment with certain spatial and temporal constraints.

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| Class | Activities | Class | Activities |
| --- | --- | --- | --- |
| Work/School | Work | Recreation/ Entertainment | Jogging, biking, roller-skating |
| | School (only if you are a student) | | Fitness center |
| Maintenance | Meals | | Golf |
| | Meal preparation | | Spectator sports |
| | Shower/dress | | Bars |
| | Cleaning/Maintenance (at home) | | Movies in theaters |
| | Pick-up/drop-off kids | | Watching videos |
| | Pick-up/drop off others | | Regular TV programs |
| | Attending to children (at home) | | Browsing Web sites |
| Shopping/Services | Major Grocery (10+ items) | | Relaxation/Rest |
| | Minor Grocery (<10 items) | | Hobbies at home (crafts, gardening, and others) |
| | House wares/clothing/personal items | | Pleasure driving |
| | Drug Store | | |
| | Mostly browsing | | |
| | Convenience store | | |
| | Medical care | Social | Visiting |
| | Personal services (Hair, nails ...) | | Hosting visitors |
| | Professional services (dry clean, auto repair…) | | Phone/email (over 10 minutes) |
| | Banking/ATM | | Church and other religious events |
| | Post office/Shipping | | Volunteer work |
| | Library | | |
| | Gas station | | |
| | Video rental store | | |

Table 1 Activity Functional Classes

| Activity Class | Spur | | Within day | | Within week | | Before week | | Missing | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Work/School | 200* | 23.09%* | 65 | 7.51% | 182 | 21.02% | 376 | 43.42% | 43 | 4.97% | 866 |
| Social | 129 | 38.74% | 32 | 9.61% | 42 | 12.61% | 116 | 34.83% | 14 | 4.20% | 333 |
| Shopping /Services | 113 | 36.81% | 40 | 13.03% | 32 | 10.42% | 100 | 32.57% | 22 | 7.17% | 307 |
| Maintenance | 304 | 36.85% | 50 | 6.06% | 168 | 20.36% | 196 | 23.76% | 107 | 12.97% | 825 |
| Recreation/ Entertainment | 689 | 59.50% | 47 | 4.06% | 140 | 12.09% | 202 | 17.44% | 80 | 6.91% | 1158 |
| Total | 1435 | 41.13% | 234 | 6.71% | 564 | 16.17% | 990 | 28.37% | 266 | 7.62% | 3489 |

Goodness of fit statistics

| Null Hypothesis | Pearson $\chi^2$ | Degree of Freedom (DF) | Significance (Sig) |
|---|---|---|---|
| Complete independence | 369.422 | 12 | 0.00 |

*

| | |
|---|---|
| Number of events In the category (N) | N / Row total |

Note: The same cell arrangement applies to all of the following tables.

Table 2 Two-way Table of Activity Class and Scheduling Horizon

| Duration ( t ) | Spur | | Within day | | Within week | | Before week | | Missing | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| t <= 60 min | 857 | 47.06% | 100 | 5.49% | 264 | 14.50% | 438 | 24.05% | 162 | 8.90% | 1821 |
| 60 min < t <= 180 min | 485 | 39.92% | 99 | 8.15% | 206 | 16.95% | 339 | 27.90% | 86 | 7.08% | 1215 |
| t > 180 min | 93 | 20.53% | 35 | 7.73% | 94 | 20.75% | 213 | 47.02% | 18 | 3.97% | 453 |
| Total | 1435 | 41.13% | 234 | 6.71% | 564 | 16.17% | 990 | 28.37% | 266 | 7.62% | 3489 |

| Goodness of fit statistics | | | |
|---|---|---|---|
| Null Hypothesis | Pearson $\chi^2$ | DF | Sig. |
| Complete independence | 143.6365 | 6 | 0 |

Table 3 Two-way Table of Activity Duration and Scheduling Horizon

| Location | Activity Class | Spur | | Within Day | | Within week | | Before week | | Missing | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| In-Home | Work/School | 150 | 40.98% | 35 | 9.56% | 76 | 20.77% | 79 | 21.58% | 26 | 7.10% | 366 |
| | Social | 100 | 55.87% | 14 | 7.82% | 8 | 4.47% | 49 | 27.37% | 8 | 4.47% | 179 |
| | Maintenance | 299 | 41.07% | 41 | 5.63% | 134 | 18.41% | 158 | 21.70% | 96 | 13.19% | 728 |
| | Recreation/ Entertainment | 614 | 65.25% | 31 | 3.29% | 104 | 11.05% | 123 | 13.07% | 69 | 7.33% | 941 |
| In-Home Total | | 1168 | 52.45% | 121 | 5.43% | 323 | 14.50% | 414 | 18.59% | 201 | 9.03% | 2227 |
| Out-of-Home | Work/School | 50 | 10.00% | 30 | 6.00% | 106 | 21.20% | 297 | 59.40% | 17 | 3.40% | 500 |
| | Social | 29 | 18.83% | 18 | 11.69% | 34 | 22.08% | 67 | 43.51% | 6 | 3.90% | 154 |
| | Shop/Services | 113 | 36.8% | 40 | 13.03% | 32 | 10.42% | 100 | 32.57% | 22 | 7.17% | 307 |
| | Maintenance | 5 | 5.15% | 9 | 9.28% | 34 | 35.05% | 38 | 39.18% | 11 | 11.34% | 97 |
| | Recreation/ Entertainment | 75 | 34.56% | 16 | 7.37% | 36 | 16.59% | 79 | 36.41% | 11 | 5.07% | 217 |
| Out-of-Home Total | | 267 | 21.16% | 113 | 8.95% | 241 | 19.10% | 576 | 45.64% | 65 | 5.15% | 1262 |
| Grand Total | | 1435 | 41.13% | 234 | 6.71% | 564 | 16.17% | 990 | 28.37% | 266 | 7.62% | 3489 |

Goodness of fit statistics

| Models* | Independent factor | Pearson $\chi^2$ | DF | Sig. |
|---|---|---|---|---|
| Complete independence | NA | 1896.8088 | 31 | .0000 |
| Independence of one factor | Activity type | 1379.1327 | 28 | 4.-273 |
| | Location | 1260.2005 | 19 | 1.-255 |
| | Planning horizon | 711.4841 | 27 | 1.-132 |
| Conditional independence | Activity type – Location | 1006.2102 | 16 | 5.-204 |
| | Planning horizon – Location | 367.6989 | 15 | 4.E-69 |
| | Activity type – planning horizon | 318.1183 | 24 | 4.E-53 |
| Homogeneous association | NA | 59.4892 | 12 | 3.E-08 |

*Saturated model is not listed, since its test statistics is always 0.

Table 4 Three-way Table of Location, Activity Class, and Scheduling Horizon

| Location | Duration | Spur | | Within Day | | Within Week | | Before Week | | Missing | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| In-Home | t <= 60 min | 693 | 53.93% | 50 | 3.89% | 171 | 13.31% | 246 | 19.14% | 125 | 9.73% | 1285 |
| | 60 min < t <= 180 min | 410 | 51.96% | 56 | 7.10% | 119 | 15.08% | 137 | 17.36% | 67 | 8.49% | 789 |
| | t > 180 min | 65 | 42.48% | 15 | 9.80% | 33 | 21.57% | 31 | 20.26% | 9 | 5.88% | 153 |
| In-Home Total | | 1168 | 52.45% | 121 | 5.43% | 323 | 14.50% | 414 | 18.59% | 201 | 9.03% | 2227 |
| Out-of-Home | t <= 60 min | 164 | 30.60% | 50 | 9.33% | 93 | 17.35% | 192 | 35.82% | 37 | 6.90% | 536 |
| | 60 min < t <= 180 min | 75 | 17.61% | 43 | 10.1% | 87 | 20.42% | 202 | 47.42% | 19 | 4.46% | 426 |
| | t > 180 min | 28 | 9.33% | 20 | 6.67% | 61 | 20.33% | 182 | 60.67% | 9 | 3.00% | 300 |
| Out-of-Home Total | | 267 | 21.16% | 113 | 8.95% | 241 | 19.10% | 576 | 45.64% | 65 | 5.15% | 1262 |
| Grand Total | | 1435 | 41.13% | 234 | 6.71% | 564 | 16.17% | 990 | 28.37% | 266 | 7.62% | 3489 |

Goodness of fit statistics

| Models | Independent factor | Pearson $\chi^2$ | DF | Sig. |
|---|---|---|---|---|
| Complete independence | NA | 850.5558 | 17 | 8.-170 |
| Independence of one factor | Duration | 317.9108 | 14 | 2.E-59 |
| | Location | 561.5123 | 11 | 2.-113 |
| | Planning horizon | 506.7803 | 15 | 2.E-98 |
| Conditional independence | Planning horizon – Location | 378.3833 | 9 | 6.E-76 |
| | Duration – Location | 140.9578 | 8 | 1.E-26 |
| | Planning horizon – Duration | 100.4238 | 12 | 5.E-16 |
| Homogeneous association | NA | 37.5084 | 6 | 1.E-06 |

Table 5 Three-way Table of Location, Duration, and Scheduling Horizon

| Activity Type | Duration | Spur | | Within Day | | Within Week | | Before Week | | Missing | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Non-work | t <= 60 min | 782 | 47.83% | 88 | 5.38% | 231 | 14.13% | 381 | 23.30% | 153 | 9.36% | 1635 |
| | 60 min < t <= 180 min | 391 | 46.83% | 70 | 8.38% | 129 | 15.45% | 183 | 21.92% | 62 | 7.43% | 835 |
| | t > 180 min | 62 | 40.52% | 11 | 7.19% | 22 | 14.38% | 50 | 32.68% | 8 | 5.23% | 153 |
| Non-work total | | 1235 | 47.08% | 169 | 6.44% | 382 | 14.56% | 614 | 23.41% | 223 | 8.50% | 2623 |
| Work | t <= 60 min | 75 | 40.32% | 12 | 6.45% | 33 | 17.74% | 57 | 30.65% | 9 | 4.84% | 186 |
| | 60 min < t <= 180 min | 94 | 24.74% | 29 | 7.63% | 77 | 20.26% | 156 | 41.05% | 24 | 6.32% | 380 |
| | t > 180 min | 31 | 10.33% | 24 | 8.00% | 72 | 24.00% | 163 | 54.33% | 10 | 3.33% | 300 |
| Work Total | | 200 | 23.09% | 65 | 7.51% | 182 | 21.02% | 376 | 43.42% | 43 | 4.97% | 866 |
| Grand Total | | 1435 | 41.13% | 234 | 6.71% | 564 | 16.17% | 990 | 28.37% | 266 | 7.62% | 3489 |

| Goodness of fit statistics | | | | |
|---|---|---|---|---|
| Models | Independent factor | Pearson $\chi^2$ | DF | Sig. |
| Complete independence | NA | 1113.2524 | 17 | 5.-226 |
| Independence of one factor | Work | 753.8926 | 11 | 1.-154 |
| | Planning horizon | 260.9230 | 15 | 7.E-47 |
| | Duration | 706.8397 | 14 | 9.-142 |
| Conditional independence | Work – Planning horizon | 136.5977 | 9 | 5.E-25 |
| | Planning horizon – Duration | 79.0710 | 12 | 6.E-12 |
| | Duration – Work | 495.6480 | 8 | 6.-102 |
| Homogeneous association | NA | 27.1544 | 6 | .0001 |

Table 6 Three-way Table of Work, Duration, and Scheduling Horizon

| Activity Type | Participant | Spur | | Within Day | | Within Week | | Before Week | | Missing | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Non-work | Alone | 654 | 51.01% | 74 | 5.77% | 137 | 10.69% | 305 | 23.79% | 112 | 8.74% | 1282 |
| | Family Members | 473 | 44.45% | 69 | 6.48% | 190 | 17.86% | 248 | 23.31% | 84 | 7.89% | 1064 |
| | Others | 108 | 38.99% | 26 | 9.39% | 55 | 19.86% | 61 | 22.02% | 27 | 9.75% | 277 |
| Non-work total | | 1235 | 47.08% | 169 | 6.44% | 382 | 14.56% | 614 | 23.41% | 223 | 8.50% | 2623 |
| Work | Alone | 186 | 25.76% | 57 | 7.89% | 159 | 22.02% | 282 | 39.06% | 38 | 5.26% | 722 |
| | Family Members | 12 | 37.50% | 5 | 15.63% | 2 | 6.25% | 10 | 31.25% | 3 | 9.38% | 32 |
| | Others | 2 | 1.79% | 3 | 2.68% | 21 | 18.75% | 84 | 75.00% | 2 | 1.79% | 112 |
| Work total | | 200 | 23.09% | 65 | 7.51% | 182 | 21.02% | 376 | 43.42% | 43 | 4.97% | 866 |
| Grand Total | | 1435 | 41.13% | 234 | 6.71% | 564 | 16.17% | 990 | 28.37% | 266 | 7.62% | 3489 |

Goodness of fit statistics

| Models | Independent factor | Pearson $\chi^2$ | DF | Sig. |
|---|---|---|---|---|
| Complete independence | NA | 757.1295 | 17 | 6.-150 |
| Independence of one factor | Party | 512.4965 | 14 | 2.-100 |
| | Planning horizon | 303.8909 | 15 | 9.E-56 |
| | Work | 697.2015 | 11 | 2.-142 |
| Conditional independence | Work – Party | 476.4366 | 8 | 8.E-98 |
| | Planning horizon – Party | 107.2373 | 12 | 2.E-17 |
| | Work – Planning horizon | 255.6985 | 9 | 6.E-50 |
| Homogeneous association | NA | 63.4119 | 6 | 9.E-12 |

Table 7 Three-way Table of Work, Participants, and Scheduling Horizon

| Number of stops in tour | Stop Sequence | Spur | | Within day | | Within week | | Before week | | Missing | | Meals | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| One | 1st | 142 | 17.44% | 48 | 5.90% | 143 | 17.57% | 374 | 45.95% | 32 | 3.93% | 75 | 9.21% | 814 |
| One stop total | | 142 | 17.44% | 48 | 5.90% | 143 | 17.57% | 374 | 45.95% | 32 | 3.93% | 75 | 9.21% | 814 |
| Two* | 1st | 20 | 12.66% | 11 | 6.96% | 33 | 20.89% | 64 | 40.51% | 10 | 6.33% | 20 | 12.66% | 158 |
| | 2nd | 43 | 29.25% | 16 | 10.88% | 14 | 9.52% | 44 | 29.93% | 11 | 7.48% | 19 | 12.93% | 147 |
| Two stop total | | 63 | 20.66% | 27 | 8.85% | 47 | 15.41% | 108 | 35.41% | 21 | 6.89% | 39 | 12.79% | 305 |
| Three ** | 1st | 10 | 14.71% | 3 | 4.41% | 10 | 14.71% | 35 | 51.47% | 5 | 7.35% | 5 | 7.35% | 68 |
| | 2nd | 12 | 22.64% | 10 | 18.87% | 5 | 9.43% | 13 | 24.53% | 2 | 3.77% | 11 | 20.75% | 53 |
| | 3rd | 12 | 25.00% | 10 | 20.83% | 8 | 16.67% | 7 | 14.58% | 6 | 12.50% | 5 | 10.42% | 48 |
| Three stop total | | 34 | 20.12% | 23 | 13.61% | 23 | 13.61% | 55 | 32.54% | 13 | 7.69% | 21 | 12.43% | 169 |
| Four*** | 1st | 1 | 11.11% | 0 | 0.00% | 3 | 33.33% | 4 | 44.44% | 0 | 0.00% | 1 | 11.11% | 9 |
| | 2nd | 2 | 22.22% | 3 | 33.33% | 1 | 11.11% | 1 | 11.11% | 0 | 0.00% | 2 | 22.22% | 9 |
| | 3rd | 2 | 18.18% | 2 | 18.18% | 3 | 27.27% | 1 | 9.09% | 1 | 9.09% | 2 | 18.18% | 11 |
| | 4th | 3 | 27.27% | 0 | 0.00% | 4 | 36.36% | 4 | 36.36% | 0 | 0.00% | 0 | 0.00% | 11 |
| Four stop total | | 8 | 20.00% | 5 | 12.50% | 11 | 27.50% | 10 | 25.00% | 1 | 2.50% | 5 | 12.50% | 40 |

* Test for independence of all factors of two-stop tours: $\chi^2 = 20.26208$ d.f.= 4 (p=0.0004432829) (missing records omitted, but meals included)

** Test for independence of all factors of three-stop tours: $\chi^2 = 27.66633$ d.f.= 8 (p=0.0005420354) (missing records omitted, but meals included)

***Tours of more than four stops are excluded from this table for low occurrence.

Table 8 Scheduling Structure of Tours

| Event Type | Travel time ( t ) | Spur | | Within day | | Within week | | Before week | | Missing | | Meals | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Non - Work | t < 10min | 70 | 24.05% | 11 | 3.78% | 38 | 13.06% | 78 | 26.80% | 16 | 5.50% | 78 | 26.80% | 291 |
| | 10 <= t < 30 min | 90 | 23.32% | 44 | 11.40% | 55 | 14.25% | 128 | 33.16% | 26 | 6.74% | 43 | 11.14% | 386 |
| | t >= 30 | 22 | 17.19% | 21 | 16.41% | 21 | 16.41% | 40 | 31.25% | 7 | 5.47% | 17 | 13.28% | 128 |
| | Missing | 21 | 35.59% | 2 | 3.39% | 8 | 13.56% | 22 | 37.29% | 1 | 1.69% | 5 | 8.47% | 59 |
| Work total | | 203 | 23.50% | 78 | 9.03% | 122 | 14.12% | 268 | 31.02% | 50 | 5.79% | 143 | 16.55% | 864 |
| Work | t < 10min | 28 | 17.50% | 5 | 3.13% | 41 | 25.63% | 76 | 47.50% | 10 | 6.25% | 0 | 0.00% | 160 |
| | 10 <= t < 30 min | 18 | 7.00% | 19 | 7.39% | 46 | 17.90% | 168 | 65.37% | 6 | 2.33% | 0 | 0.00% | 257 |
| | t >= 30 min | 1 | 1.54% | 5 | 7.69% | 13 | 20.00% | 45 | 69.23% | 1 | 1.54% | 0 | 0.00% | 65 |
| | Missing | 1 | 10.00% | 1 | 10.00% | 5 | 50.00% | 3 | 30.00% | 0 | 0.00% | 0 | 0.00% | 10 |
| Non work total | | 48 | 9.76% | 30 | 6.10% | 105 | 21.34% | 292 | 59.35% | 17 | 3.46% | 0 | 0.00% | 492 |
| Grand total | | 251 | 18.51% | 108 | 7.96% | 227 | 16.74% | 560 | 41.30% | 67 | 4.94% | 143 | 10.55% | 1356 |

Goodness of fit statistics*

| Models | Independent factor | Pearson $\chi^2$ | DF | Sig. |
|---|---|---|---|---|
| Complete independence | NA | 131.4291 | 17 | 1.E-19 |
| Independence of one factor | Planning horizon | 129.5230 | 15 | 3.E-20 |
| | Work | 96.0158 | 11 | 1.E-15 |
| | Travel time | 49.9316 | 14 | 6.E-06 |
| Conditional independence | Work – Planning horizon | 94.4929 | 9 | 2.E-16 |
| | Work – Travel time | 13.9641 | 8 | .0827 |
| | Planning horizon – Travel time | 47.7102 | 12 | 4.E-06 |
| Homogeneous association | NA | 11.4516 | 6 | .0754 |

*The hypothesis testing omitted missing and meals

Table 9 Three-way Table of Work, Travel Time, and Scheduling Horizon