

# **Real-time Tracking of Activity Scheduling/Schedule Execution Within**

## **A Unified Data Collection Framework**

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## **ABSTRACT**

One of the major foci in transport research is to identify the temporal-spatial decision making structure embedded in activity scheduling and its linkage to actual activity execution. The latter part of the question hasn't been able to be explored explicitly in real life situation due to the lack of effective data collection means. The paper presents a real-time travel/activity survey system that incorporates the extraction of activity scheduling and execution information within one unified data collection framework. These "revealed" data could be used for explicitly defining the mechanism of how people's activity schedules dynamically adapt to social-demographic and temporal-spatial constraints and finally leads to the observed activity-travel patterns.

Key words: activity scheduling, schedule execution, real-time system, multi-modal interface

## 1. INTRODUCTION

Travel is generated from the competing needs to participate in activities. These needs can be further classified into three categories: maintenance needs (work or business related), subsistence needs (shopping etc.) and leisure needs (recreation etc.). Typical activity-based travel behavior studies are oriented towards examining people's travel activities within the context of time and money allocation among the various activity needs. The interwoven travel/activities behavior and people's decisions with respect to them cannot be meaningfully interpreted in isolation from the general framework of activity time use and Hagerstrand's (1970) time-space geography. The various constraints enforced by the environment (as identified by Hagerstrand (1970)- capability constraints, coupling constraints and authority constraints) potentially limit people's ability to trade off time for achieving a bigger activity and action scope. This entails complex decision making with regard to what activity to pursue, when, where, and what people are involved with when they are trying to fulfill various activity needs (Garling, 1989). Many years of discrete-choice (travel) activity analysis have shown that the interdependent decisions regarding the various alternative activity attributes and derived trips might include complex choices of many aspects—activity location, travel mode (if a trip is involved), starting time etc. (Ben-Akiva and Lerman, 1985). These choices, however, only represent the resulting activity-travel patterns derived from the individual's decision-making process. The computational process that generated these outputs in a human's mind is the more complicated part to delve into. Classified as cognitive activity, scheduling is conducted implicitly, the details of which can't be revealed unless structurally organized questions are asked to elicit them piece-by-piece. Two existing propositions – the successive refinement model and the opportunistic model—reflect different views and understandings about the scheduling process (Hayes-Roth and Hayes-Roth, 1979). Although Hayes-Roth and Hayes-Roth (1979) favor the latter model (as they proposed and tested with the “think aloud” protocol), the elements used to differentiate the two different views (top-down versus multi-directional processing, complete versus incremental planning, hierarchical versus

heterarchical plan structures) are yet to be further examined in more empirical studies. As they have suggested in their article, people with different personal characteristics may choose to deal with the scheduling problem with the strategies that best suits the scenario. For example, the continuous 24 hours on weekdays is divided by fixed working schedules into several segments. The home-work-home (travel) activity pattern can serve as the skeleton of people's activity schedules, which can be refined further in steps. However, the formulation of the activity schedule on weekends could be far more complex than what we can understand with the current research methodology (Damm and Lerman, 1981). Systematic techniques need to be developed for shifting the data collection emphasis onto the information collection of the activity schedules and sequences in space and time and the interaction of them with the time-space constraints on individual behavior. Although the long-tradition activity-based approach outperforms the trip-based studies in many aspects, the conventional recall and recording method for data collection has become the major constraint that hinders the retrieval of more accurate data and the use of a more comprehensive data collection design.

In the past, the scientific community has been seeking an effective means to observe the process of decision-making actually being undertaken in the mind for truly understanding its inner working gears. Hayes-Roth and Hayes-Roth's (1979) tracing of the scheduling process by verbal protocol is a successful attempt. Ericsson and Simon first formally proposed the method during the early 1980's (Ericsson and Simon 1980, 1984). The method elicits the details of the cognitive process embedded in the decision-making task by asking the interviewee or survey respondents to speak aloud their undergoing mental activities. The action of "think aloud" occurs concurrently with the decision-making task being performed. As the information collected by "Think Aloud" method originates from the "real-time" cognitive process that stores it in the short-term memory (STM), data derived are not subject to the possible distortion effects of any intermediate encoding or interpreting process. The only possible "negative" effect is that the duration of the whole decision-making process may be elongated a little bit due to the need to verbalize the originally silent cognitive process (Ericsson and Simon, 1980). However, the methodology requires extensive

personnel supervision and recording efforts. The cost to analyze the data derived from it is even higher (Smith et al., 1982, 1984). This means the method could be useful in an in-lab experimental setting, but might not be a good choice for large-scale data collection efforts. In order to fully examine the activity scheduling behavior and its execution status in real-life activity implementation, an in-field data collection method is required, which enables continuous activity scheduling and execution observation over a relatively long survey period.

## **2. RESEARCH OBJECTIVES**

As activity scheduling could continuously evolve over time even while an activity is being undertaken, it is reasonable to conceive a real-time data collection system to capture the activity scheduling process that is driven by time and events. If such a system can be activated by multi-modal input, its use would facilitate and encourage the reporting of en-route activity (destination) change, the previously under-reported short trips, the multi-stop trips and the associated activities with them. Hence it not only provides the maximum information about the not-well-understood activity-related decision making process, but would further improve the analysis of the trip-chaining phenomenon and complex travel patterns. Moreover, the rapid development in speech recognition and text-to-speech make it possible to integrate “think aloud” protocol into in-field devices for capturing the dynamic scheduling behavior with the reduced information loss.

This research proposes a real time activity scheduling /execution data collection system augmented with a multi-modal input interface, following a client-server interface system design. It helps to achieve the following objectives for activity scheduling/execution data collection efforts:

1. Capture the dynamic activity scheduling/execution behavior over a long time survey period within a unified data collection framework. Differentiate routine activity pursuits from the observed activity/travel patterns that result from the explicit scheduling behavior. As data are collected in near real-time by its features for in-field use (with a Pocket PC and GPS) and the direct link of the survey unit to a central data server (with wireless network connection), the

system has the capability of capturing the interleaving activity agenda generation and activity scheduling process and recording the associated activity-travel patterns under the guidance of refined activity schedules.

2. Monitor the travel data collection process in real time by wireless networking and respond to the possible data errors in a timely way. Under the real-time scenario, behavior that happens infrequently is easier to capture by the survey equipment, which helps researchers differentiate the random variations in people's travel activities from the genuine trend change. By augmenting the existing interface of the data collection devices with speech input-output functions, it is expected that the system will be useful for simulating the role of interviewers on the past home interview surveys who help the respondent "think aloud" the subconscious activity scheduling information, which varies with the changing spatio-temporal context.

### **3. PAST EFFORTS**

Among past efforts, one comprehensive approach for fulfilling an activity scheduling survey is the CHASE survey program by Doherty and Miller (2000), which is the first successful attempt that provides the real-life scheduling data for researchers who work on general activity scheduling and execution. This activity scheduling survey assumes that people generate next-week activity agenda during the weekends immediately before the week begins. Daily activity scheduling actions are recorded by revolving the agenda needs via Internet-connected home computers. This electronic survey procedure became the basis of Lee's work on REACT! (Lee et al., 2001; Lee and McNally, 2000). Survey results using either procedure are encouraging in terms of their success in capturing the dynamic activity scheduling processes over a relatively long survey period (one week), but both lack the ability to trace the actual activity-travel execution due to the mobility constraints of the computing device they use. Many current computer-assisted travel surveys have incorporated the use of a minicomputer, GPS and Geographic Information Systems (GIS) for enhancing the data collection device's mobility and facilitate such kind of activity-travel data capturing through

automatic features. A typical example is the semi-automatic data collection device used in the Lexington Travel Survey (1997). In that survey an on-board mini-computer coupled with a connecting GPS module made possible the collection of physical travel paths and travel times with considerable accuracy. To facilitate the efficient capturing of spatial information during a travel survey, the computer-based intelligent travel survey system by Resource Systems Group, Inc. (<http://www.fhwa.dot.gov/ohim/trb/rsgprpt.pdf>, 1999) contributed from a different perspective by using the interactive geocoding and other intelligent functions provided by GIS to reduce the reporting burden on the survey respondents. The integrated activity scheduling and execution survey required by this research would also benefit from the new features that have been utilized in these travel survey applications.

However, it should be noted that the approach that incorporates new technology to improve travel survey automation and data quality is not cost-free. It has been noted that problems often occur when GPS is used for logging travel traces, as GPS is not always reliable throughout the entire trip-recording period (Lexington Travel Survey, 1997). When GPS signals deteriorate or are blocked by the surrounding buildings, bad data creeps into records easily. If the data is not retrieved in real time, data verification and correction could only be performed after the data collection devices had been returned. An additional recall review of the respondents who participated in the survey is usually inevitable for recovering these data errors that potentially cause bias in further analysis. If some of the errors turn out to be unrecoverable, the activity/trip records with errors will have to be discarded otherwise further research based on the data will be compromised. Generally, an activity/travel survey could last for one week or longer. It is conceivable that information from such a recall review depends on the respondents' retrospective memory hence could not be as accurate as the researchers might desire. In addition, using a keyboard to replace the traditional paper and pen as a means of information input during a travel/activity survey may actually be cumbersome for outdoor data collection or even may slow down the input speed if the respondents do not have much experience in computer operation. Another disadvantage associated with the use of standalone computing devices for travel/activity

surveys is that the duration of data collection is restricted by the capacity of the computing device. If the activity/travel data collection device is designed to be portable, after a certain period, the device needs to be collected from the survey participants and the data stored on the device must be flushed to and processed on a data server. In this sense, the maximum continuous collection duration is subject to the storage capacity of the computing devices used. To integrate new features into the current system for the integrated activity scheduling/execution data collection, these issues need to be addressed with care.

#### **4. CONCEPTUAL FRAMEWORK**

The survey system developed in this research adopts a single-server, multiple-clients architecture design (Figure 1). It conceptually consists of two main components—a central database server and the multiple mobile data collection terminals (used by survey respondents). The central database server, located at a fixed location, continuously accepts data uploading requests from the terminals carried by the activity scheduling/execution survey respondents. Received data is preprocessed and stored on the central data server in a research-friendly format.

The mobile data collection terminal consists of four modules--- multi-modal input interface, GPS unit with antenna, mobile networking card and portable computing device. The central theme of the data collection terminal in the system revolves around the Pocket PC. It provides a window-based operating system with color screen. Speech recognition/output and tactile/visual display are multiplexed to provide the survey respondents a multi-modal interface. Either approach serves as an alternative to the other in cases when one is inadequate to handle the current data input situation. Compared to Palm/PDA, the Pocket PC outperforms with its colorful screen for survey question highlighting, faster processing speed for accommodating the need of using speech recognition on it, and more memory storage to keep logging the activity-travel data when the system goes out of wireless service coverage. Furthermore, the expansion pack of the Pocket PC provides more flexibility to accommodate the wireless PC card, GPS module, additional memory

and battery power. Compared with a typical computerized activity scheduling system (e.g. CHASE) (Doherty and Miller, 2000) and Internet-based travel survey system (e.g. iCHASE and later REACT!) (Lee et al., 2001; Lee M.S. & McNally M. G., 2000), the real-time mobile system with wireless connection doesn't restrict the location for data collection and is easy to carry around by survey respondents for in-situation data input. Its voice input capability potentially extends the system's sample coverage to computer illiterate and physically challenged people.

In addition to the system configuration elaborated above, several key concerns about mobile devices should be emphasized here. First, in our wireless scenario, data collection terminals and data server communicate by TCP/IP protocol. Note that an application based on TCP/IP will have a problem when the data collection terminal moves outside of the coverage of the subscribed wireless service. Other worse situations might include the network overload, time-out delays and the reduced efficiency of TCP/IP protocol in a WWAN scenario (Tsaoussidis and Matta, 2002). These reasons contribute to most of the difficulty in maintaining the communication quality while the mobile data collection terminals are roaming in different travel modes with various speeds or crossing the boundaries between multiple wireless network control areas. It is necessary to cache and replicate the un-uploaded data on the data collection client side to avoid potential data loss due to the communication problem. With a disk space that functions as a data storage buffer, the system will be able to store the collected data temporarily on the terminal data storage when the wireless connection is not available or degraded.

Second, portable devices have severe constraints on power consumption (Zaslavsky and Tari, 1998). The capacity of the supporting batteries delimits the working duration of the data collection terminal. However, addition of more batteries to the devices would compromise its portability. For universal use of the data collection system, the system's battery can't weigh more than what is recommended for a pedestrian to carry and must be able to work in a heterogeneous environment. There are two approaches to deal with the problem. One is to support the system with a hybrid redundant power system. This involves using each power scheme to suit its best working scenario

and allowing the other power backups to recharge at the same time (Hall, 2002). On the other hand, some built-in power reservation features would be helpful for the device to work for long hours without battery replacement or battery recharge. A preset threshold value about the usage idleness or the amount of messages incoming and outgoing could serve as the criterion to turn on/off the screen or hard disk. As typically there is an expensive startup cost associated with the wireless modem attached to the Pocket PC, it is better for it to remain at ready state all the time (Zaslavsky and Tari, 1998).

For the pre-analysis of the received data, the server is the most suitable site to check the consistency and logical coherence of collected data. This approach is similar to the post-interview phase conducted for a typical travel survey. In that case, the respondent is asked by interviewers to reconstruct and confirm the activities or trips they listed in the activity-travel diary. The personnel hired for the interview holds the responsibility of detecting any inconsistency that may indicate that the respondents have made mistakes in following the survey instructions, or didn't fill in the survey contents thoroughly and completely. In general, the process is time and energy consuming for both the interviewer and respondents. After the introduction of computerized device into activity-travel survey, the onerous checking task could be delegated into a data collection system as in ALBATROSS with the SYLVIA system (Arentze et al., 1999). A multi-level set of logical rules can be organized into modules to diagnose and repair the fixable errors and inconsistency in the collected data. The demands of activity scheduling (execution) survey are reduced dramatically when only those irresolvable record inconsistencies are returned to the respondents for further clarification.

With the aim of serving the data collection need regarding activity/trip scheduling, special attentions of the data collection survey are paid to the underlying mechanism of how respondents make planning decisions prior to the actual execution of activities/travels. Until recently little has been known regarding the strategies people use for sequencing and committing activities. According to Garling et al. (1998), when people are forming an intention to execute an activity in

a future time, the intention itself may be unrealistic because of ignorance of the potential conflicts embedded in other concurrent planning. The intentions would be easily deferred or given up under the time pressure in some cases (Garling et al. 1999), while sometime the planner might even forget the original intention, hence totally forgetting the planned activity. Thus a sound survey system should be able to capture all the three aspects of the travel activity-travel scheduling process mentioned above. A uniform tabular visual interface for collection of people's decisions for trip planning may not be the best solution. In some cases, people don't use the help of a computer program (such as a task scheduler) or even a booklet to keep track of activities that shall be performed at a future time if his/her time budget is not subject to tight constraints or his/her daily activities are extremely regular. The use of a tabular task scheduler potentially reinforces the survey respondents' awareness of the need to plan their activities with the various constraints thoroughly considered. Hence their activity plan construction and subsequent behavior can be inadvertently affected (Doherty and Miller, 2000). In this sense, the data collection practice regarding activity scheduling should conform to respondents' living customs. The survey program should never function as a memory jogger or scheduling tool to help the respondents track daily tasks. However, the respondents are allowed to "talk"/type into the Pocket PC whenever an activity planning decision is being made. Data are collected in a way similar to a "think aloud" method (Ericson and Simon, 1984). The types of decision-making include "add/delete activity or adjusting scheduled time" operations as in Ettema et al. (1994)'s simulation program or in CHASE (Doherty and Miller, 2000). This approach also corresponds to the common experience that activity scheduling doesn't occur in a fixed point along the time axis but rather continuously evolves.

Besides the focus on the activity scheduling action, the data collection system is also obligated to keep track of the execution consequence of the planned activity schedule in order to measure the degree of consistency between the activity planning and its actual implementation. Two types of plan-execution inconsistency can be differentiated, as argued by Garling et al. (1998). One case is "false alarm", which means the survey respondent made a plan for the activity but didn't perform

it. This includes the cases of activity conflicts and the “not for sure” plan for an activity. The other case is “miss”, which indicates that the survey respondent didn’t show an intention to perform the activity before and didn’t list it in the activity plan but the activity was actually performed. In our activity scheduling (execution) survey, for a “false alarm”, the system marks the execution status of the planned activity as “delete from activity plan”; for “miss”, the system will remind the survey respondent that the activity is unplanned in nature. It will also inquire of him/her if the planning decision has been forgotten to input into the system. If not, the “miss” activity will be recorded as a type of impulsive action.

## **5. SURVEY METHODOLOGY AND SYSTEM IMPLEMENTATION**

### **5.1 Survey Program Organization and Questionnaire Forms**

The survey program on the Pocket PC is organized into a series of forms. To reduce the communication cost between mobile terminal and central data server, the survey program is designed to function as a fat client. That means, except that the central data server handles data storage and management, all the data entry, consistency checking, voice recognition tasks are to be performed on the mobile terminals.

The start-up form of the survey presents the survey respondents with the four module components (“Personal Info and Week Schedule”, “Schedule Activities or Refine the Schedules”, “Trace Activity Implementation” and “Answer Questions related to Unfulfilled activities in schedules”) of the activity scheduling and implementation survey (Figure 2). Each of the components is symbolized as and linked to the corresponding button, which leads the survey respondent through the process of accomplishing a specific survey task after being triggered by a click action.

#### *5.1.1 Personal Info and Week Schedule Module*

The Personal Info and Week Schedule module serves the role of the up-front interview in traditional activity/travel survey. In the module, personal demographic data and activity/travel-related spatial information are collected before the beginning of the main survey for survey management and the later activity scheduling/implementation model construction. A preliminary activity schedule for the coming survey period is also solicited in the component for identifying those “peg” activities with less flexibility and relative high repetition rate.

Different from CHASE and REACT!, survey unit in our case is individual rather than household. Only the information about the individual who responds to the survey would be collected. The questions to be asked include:

- (1) Personal Demographic Data (Figure 3):
  1. First Name and Last Name: Provision of this information depends on willingness. It is simply for the convenience of survey supervisor to contact survey respondent in case any problem arises during the survey period with the data collection device or procedure. In the collected database, each individual respondent is identified by a unique ID, which is assigned randomly at the first time they start to use the survey program.
  2. Gender, age, marriage status, education level and possible monthly income of the survey respondent.
  3. Vehicle accessibility.
- (2) Home Address Information and Transportation Modes frequently used (Figure 4): Home address information is inquired in the form in a standard format. In addition a button link is supplied to the survey respondent for him/her to indicate the home location on a map presented via the built-in GIS mapping component implemented with ARCPAD. The additional Identify-Home-Address-On-Map requirement serves two functions in the survey: On one hand, it demands the user to double-confirm the home location to avoid the situation that a wrong address has been input and goes unnoticed into the backend central database. On the other hand, in many cases the survey respondents may depend

on the built-in GIS mapping component to indicate their activity location when the address information of that location never caught their attention or temporarily slipped out of their memory. Home location on map serves a good reference point for them to quickly indicate their planned activity location/travel destination in the real-time data collection scenario.

- (3) Types of activities the survey respondent usually conduct (Figure 5): following REACT!, the survey asks the respondents about the frequently performed activities and the associated attributes. It is beneficial to have the information for establishing the baseline activity pattern of the survey respondents. And it potentially helps us differentiate the difference between scheduled activities and unscheduled ones later. In this form, the survey respondent selects the types of those activities that they frequently conduct (at least once per month) from a predefined activity type list. Obviously, the predefined list/categorization is not sufficient to encompass the wide range of all possible activity types. A supplementary “Add Activity Type” form follows immediately to allow the survey respondents to define their own activity type with the names they deem appropriate (Figure 6).
  
- (4) Select Frequently Visited Activity Locations (Figure 7, 8): Survey respondents are required to compile a list of frequently visited locations (at least once per month) from a much-larger potential activity location set. The location set covers various possible activity locations and travel destinations. If the survey respondent can't find the frequently visited location from any of the location list, an alternative option based on mobile GIS program (ARCPAD) is provided for the user to pinpoint the location's position on an electronic map and input the location name (Figure 9). The manually captured location position is later recorded with its geographic longitude and latitude and transferred together with location name back to the central data repository.

- (5) Set up the preliminary schedule for the week (Figure 10): At the end of “Personal Info and Week Schedule” module, the survey respondent is required to record their activity intentions before the one-week survey period starts. All the preliminarily scheduled activities will be listed on the weekday tabbed panes with the arrangement sequence based on their input order. The information to collect with respect to a scheduled activity includes (Figure 11): activity type, day of the week for the activity, planned timeslot for the activity, planned activity location, the number of people that co-participate in the activity. Activity type and location are selected from two additional panes of forms (Figure 12, 13). The survey respondent may leave some details of schedule as unspecified at the time if the plan has not been well developed. Optionally the activity schedule can be refined later in the “Schedule Activities or Refine Schedules” module in real time whenever some further thinking about it comes up.

### *5.1.2 Schedule Activities or Refine Schedules Module*

Activity scheduling behavior typically occurs in a stochastic way. Even for activities pursued in habit might be subject to abrupt disturbance from some unpredictable external factors. Arbitrarily choosing fixed time or place to collect scheduling data (e.g. at the end of day /at home) seems sufficient for researchers to capture a static picture of scheduling behavior based on “what could be remembered up to now”. However, the quality of collected data could vary dramatically across the data capture periods (the time interval between adjacent data capturing actions) and the dynamics of scheduling changes are left in ignorance.

Integrating scheduling data capturing with mobile devices offers a different survey option with less time and almost no location constraints. The survey respondent has the freedom to record the activity scheduling decisions whenever the decision-making comes up to mind. After necessary information has been added, the accomplished schedules are subsequently listed on the weekday tab pane (Figure 14) with a brief description. The simple list of activity name, location and planned activity start/end time allows quick identification when later further refinement is

required. A quick click on the row brings up the “schedule an activity” form (Figure 11) again. It will be pre-filled with previous activity plan but enable the user to modify/refine the specific schedule-related information. To avoid the potential bias as the way typical schedule tool could help its user optimize the daily time use, none of schedules are ordered by time or name but listed in their original decision-making sequence.

### 5.1.3 *Trace Activity Implementation Module*

Whenever the survey respondent is going to perform an activity, “tracing activity implementation module comes into play to record activity-implementation details at real time. The whole tracing procedure is sequenced into three episodes:

(1) Activity to be implemented will be traced as in the form of Figure 15. The survey respondent is required to complete all the activity-related information that conforms to the situation of reality. A click on button 6 in turn launches ARCPAD and activates its GPS tracking functions to start capturing user’s position during the travel period (Figure 16). The strength of GPS signals captured by the Teletype GPS receiver varies with the time when the device is used and the location where the device is used. Situation happens that trip made by the survey respondent is too short hence the device doesn’t have the enough time to gain valid fix on signal, or tall buildings/trees along the travel route deteriorate the GPS signal quality dramatically and made the tracing records useless for research use. The survey program is designed to check the degree of accuracy with respect to the measurements contained in the collected GPS record. If two thirds of the total number of records is marked as invalid, an additional “Draw Route” function is offered for the survey respondent to redraw the traveled route optionally (Figure 17). After the travel information has been collected, the survey respondent clicks on the “Start Activity” button to start a timer for tracking the time duration of the activity. Before the real time tracing of the activity starts, five additional questions regarding the activity are asked to track factors potentially affecting the conformity between the schedule and actual activity implementation, ranging from weather condition, traffic condition ... to activity priority (Figure 18). Hence the answers to the weather and traffic conditions are fulfilled in a most timely manner, obliterating any possibility of

memory loss. Then the survey respondent will be directed back to the start-up form that presents the four main survey modules (Figure 19). Time duration update for the activity being pursued is displayed on the start-up form. “Done with the activity” stops the timer and the update of time duration information displayed. The form branching design won’t obstruct the survey respondent from feeding the real-time scheduling decisions information into the survey program while his/her activity pursuit is being traced.

(2) After the activity tracking and the associated travel tracing are accomplished, the survey respondent will be required to differentiate two categories of activities to be conducted (scheduled and unscheduled). Figure 20 presents to the user the list of schedules as have been input previously in module 1 and 2. If the activity to be conducted has been planned ahead, the user could navigate through the lists and indicate the associated schedule with the activity. Otherwise, a simple click on the next button will finally finish the tracking process for the activity just accomplished.

(3) If the activity just accomplished is associated with pre-planned schedule as the survey respondent indicated on “Link to Schedule” Form (Figure 20), three multiple-choice questions are used to qualify the relationship between the actual implementation of the activity and the schedule (Figure 21). Two of the questions focus on the temporal correlation between activity and schedule, i.e. if the activity starts early/late/as scheduled compared to its schedule or if the activity duration is elongated/shortened/as scheduled compared to the schedule. The last of the questions emphasizes on the spatial linkage between them, i.e. if the activity location choice in the activity implementation differs from the schedule. These relationships are not easy to demarcate by simply checking on the data solely. Thus has to be obtained from the survey respondents’ perspective.

#### *5.1.4 Answer Questions Related to Unfulfilled Activity Module*

It can be expected that some of the planned activities in the one-week-period schedule would have never been performed during the survey period. These activities are classified as unfulfilled activities. For unfulfilled activities, questions similar to those in Figure 19 are asked for later research model construction (Figure 23). Two additional questions (Figure 22) regarding factors that potentially hinder the implementation of the activity supplement the inquiry from two more aspects. As these activities have only been conceived in mind rather than actually implemented, it would be inappropriate to allocate a fixed time in each survey day for collecting answers to these questions from the survey respondents. There exists a high probability that a normal procedure of tracking activity implementation is undergoing at the time specified. To avoid the possible disruption of scheduling/activity/travel action tracing from collecting information regarding missed activity plans, module 4 functions as an flexible, independent survey unit that allows the survey respondents to take their own initiative of deciding when to answer questions related to unfulfilled activities.

### **5.2 Multi-modal User-Device Interaction**

#### *5.2.1 Human-machine “Talk” protocol*

Speech capabilities are integrated into the survey program to facilitate the interaction between survey respondents and the computing device. The data collection practice is enhanced from two perspectives: Text-to-speech and speech recognition. With the help of both, the mobile data collection terminal plays the role of survey interviewer, monitoring and recording the process of data collection via human-machine dialogues. A well-designed “Talk” protocol is built into the survey program and helps to elicit information to the maximum extent from the survey respondents. Moreover, the “talk” protocol resembles a natural way of communication. Talking to a machine rather than an interviewer is assumed to contribute to reducing the survey respondent’s privacy concern.

The “talk” protocol is formulated based on interrelated dialogues. The vocabulary used in dialogue is limited to the scope of what can be seen by the survey respondent from the survey form displayed on the Pocket PC screen and voice messages pre-configured in the survey program. Words in the vocabulary have been selected with less acoustic similarity for easy differentiation by the speech recognition engine. A “talk” dialogue would be initiated either by machine or the survey respondent. The machine typically starts a “form scope” dialogue via reading the explanatory note displayed on the top of a survey form. The action is accomplished by feeding the screen-displayed text to synthesized speech on the computing device. While the survey respondent trigger the “action scope” dialogue via requesting actions from the data collection device, e.g. saying the button label or the expected input for the current form. In the sense, the speech input performed by the survey respondents is constrained to trivial tasks such as digits spoken, choice made from a small list of options or simplistic voice commands. If the user’s voice is picked up by the microphone on the Pocket PC, processed and recognized as conforming to a pre-defined grammar, a corresponding action would be triggered and followed with certain audio/visual feedback, such as showing the called survey form or saying a message that confirms the success of the action. If the user conducts an inaccurate action or missed some part of required input, formulated auditory cues are supplied to alert the error in an amenable manner. The auditory warning is meant to supplement the traditional way of capturing users’ attentions by popping up a message box. This design takes into consideration the limits of current speech-recognition technology, i.e. computers today still can’t listen and apprehend natural speaking language as easily as does a human. Therefore it is still unrealistic (at this time) for us to expect that a machine can play an equivalent role of talking partner in a conversation (Starner, 2002).

### 5.2.2 *Speech-enabled Multi-modal Interface*

Past researches have shown that humans have the ability to handle/process simultaneous streams of input through auditory channel and focus on one of them selectively (Sawhney and Schmandt, 1998). Ideally, by saving hand and eyes’ focus on the undergoing tasks, speech input and auditory output are more suited to survey needs to feed information into data-recording equipment in a timely/convenient way. In a mobile, real-time data collection scenario as exists in a travel/activity

survey, a lot of time the survey respondents' hands or eyes are busy on tasks (e.g. when walking or driving). To collect responses from survey respondents in real-time in a mobile and heterogeneous environment, it is essential that the user's senses are not totally occupied but are still aware of surrounding people and events. Using speech capability also has significant meaning in that the data collection activity doesn't disrupt the survey respondents' normal activity/travel pursuit.

The speech-enabled interface may also help to boost survey respondent's awareness of the ongoing survey process. One of the disadvantages that associate with a self-administered travel/activity survey is that data quality and coverage partially relies on a survey respondent's enthusiasm in supplying data, which hopefully, would reflect the reality in sufficient details. However, an elongated survey period sometimes increases a survey respondents' feeling of stress and reduces their vigilance in recording travel/activity occurrences as accurately as possible. Mobile devices offer the survey supervisors the opportunity to analyze the unusual data input scenario actively. As the survey respondents are required to carry these devices in person, the data collection terminals can be programmed to actively sense data input patterns. Thus it can notify the survey respondent of any wrong operation when necessary through auditory cues or voice messages. These scenarios, for example, may include reminding a user to input activity-scheduling information in real time or reminding a user to indicate the end of activity, thus stopping the survey program timer that keeps track of the current activity duration.

Although speech input and audio output approximates human's natural means of interaction, its acceptance and wide-use in mobile and noisy environments are subject to various constraints. On the one hand, the accuracy of recognized speech input could drop dramatically with the increasing ambient noise level. Users easily may be discouraged from using the device for data input after failing several times to achieve satisfactory speech input or when misinterpretation occurs. On the other hand, speech/audio interaction is in essence sequential in time. It lacks the browsing and pre-fetching support as offered by image/text-based display (Sawhney and Schmandt, 1998). Multiplexing the strength of visual and tactile means with speech input and audio output

potentially avoids the shortcomings of each individual approach thus partially solves the problem. Actions on survey forms are allowed to trigger either by voice command or a tactile stylus click. A speech input context switches accordingly with mode changed caused by other actions. Therefore a user could choose the data input manner that works best in the current situation. The other approach that helps solve the problem is to exploit the idea of “push to talk”. As pointed out by Starner (p92, 2002): “speakers think out their sentences and articulate more clearly if they have to press a button before they speak to the computer”. The Pocket PC’s side button can be programmed to be the button switch that controls the acceptance of speech input. The switch needs to be kept pressed while the voice input is being spoken. However, the approach is not effective while the survey respondent has to use the device with hands free. A “push talk on/off” command is built in the system to control if the feature is enabled.

### *5.2.3 Survey Navigation and Monitoring by Speech*

Navigation through the survey form is supplemented via synthesized voice output. A user could directly read the explanation printed on the electrical survey form. Simultaneously, “what to do” information is read to the user through auditory output. Feedback is provided to confirm the correctness of input when important information about scheduling or activity is being collected. Crucial information input is repeated in the feedback thus confirming to the survey respondent that the information has been communicated correctly. In other cases, auditory cues (e.g. a chirping sound) are used to indicate operation success (e.g. goes to next form or a voice command is recognized as valid). The aim is to reduce the disruption of the data collection process by excessive synthesized speech information.

In addition, the data collection terminal has some more monitoring functions that potentially enhance the quality of collected activity/travel data. When it finds out that the user has spent more time on the activity than what has been scheduled, the device reminds the survey respondent by saying “Please don’t forget to indicate when the current activity ends”. Or when it reveals that the user hasn’t scheduled an activity for a long time. It will remind the survey respondents by saying

“Please input activity schedule when you have a plan for an activity.” These active reminders are trivial but play significant roles in keeping the human-machine interaction as smooth and tight as human-human interaction. The work pattern also provides a certain guarantee that the “forgot-to-input” mishap that typically happens in data collection practice is reduced to a minimum.

#### 5.2.4 *Sample usage scenario*

The following shows a demonstration of how the activity data collection system is used during an input session for the Schedule-Activity Form (Figure 11). Note that if the device has been idle for some time, the system detects that and turns off the speech input and synthesis to save power. This is called a sleep mode.

Now, suppose the device is in sleep mode—

Survey respondent says: “wake up!”

Device says: “ready for listening.”

Survey respondent says: “1” or “Activity type” or “Type of Activity”

Device shows the Select-Activity-Type Form (Figure 12) and reads the survey instructions.

Survey respondent says the activity type name: e.g. meal.

Device asks: “you have selected activity type name – meal. Is this correct?”

Survey respondent confirms: “yes”. The Select-Activity-Type Form is closed. The Schedule-activity form (Figure 11) shows up again.

Survey respondent says: “4” or “Activity location” or “location of activity”. The surrounding environment is noisy and the device can’t recognize the command. Survey respondent uses the stylus or the fingertip to click on the 4<sup>th</sup> button to select location for the activity.

Device shows the Select-Activity-Location Form (Figure 13) and reads the survey instruction.

Survey respondent has come to a quiet place and wants to try the voice input function again.

He/she says: “home”.

Device asks: “You have selected activity location – home. Is this correct?”

Survey respondent confirms: “yes”. The Select-Activity-Location form is closed. The Schedule-Activity form (Figure 11) shows up again.

Survey respondent has come to a very noisy environment. To avoid confusing the device, he/she says: “go to sleep.” Now the survey respondent wants to use stylus alone to finish inputting the form.

Device responds: “stop listening.”

### **5.3 Data organization and Infrastructure**

Several database tools compatible with mobile devices have been explored and tested to upload data collection from the mobile terminal to our central data server. SQL server CE 2.0 comes up as a compromise after weighting strengths and weaknesses of each of the approaches. Its compatibility and easy connectivity with SQL server 2000, which offers an enterprise-level central database support on a server-level machine, makes the mobile data transfer from Pocket PC to data server an easy task. Two mechanisms in SQL Server are available to fulfill the data transfer need in a mobile data collection situation. One is remote data access (RDA) and the other is merge replication (refer to SQL server CE online manual for details). RDA is most suitable for single direction data transmission either from client to server or from server to the client. When data transmission happens infrequently, RDA tends to optimize the usage of the resources on the mobile devices. Compared to RDA, merge replication allows simultaneous two-way data transfer. It follows a data publication and subscription model. In a common scenario, a few tables at the central data server are published as articles for the clients to subscribe. Any update to the database data at either the client or server side will be propagated between the two and to the other subscribers (other clients of the server) and merged into a single version.

The data transmission infrastructure is set up as follows (Figure 23). The SQL server 2000 was configured to work with Internet Information Service (IIS) on the server machine to receive data sent from the mobile devices- i.e. the Pocket PC. The collected data are organized into two types of database: “ActivitySurvey” and “ActivityData”. “ActivitySurvey”, with only one instance

configured, contains the identification information of all survey respondents. The identification information collected and stored in a local SQLSERVER CE database on the PocketPC is sent to the “ActivitySurvey” database located on the central database via the remoteSQL method provided by RDA, and managed in a centralized manner. “ActivityData” includes multiple instances, each of which stores the activity scheduling and implementation data received from a particular survey respondent. The “ActivityData” tables as specified in its schema are published on the SQL Server 2000 on the server machine. These tables include activityType, implementActivity, Schedule etc. as shown in Figure 24. The SQL Server CE on the Pocket PC subscribes to the published “articles” for keeping the data consistency between the two and downloaded as a local snapshot when the data client connects with the server for the first time. The locally stored activity-scheduling/implementation information serves fast information retrieval purpose when information supplied by the survey respondents is required to formulate some questionnaire forms. As these activity schedule and implementation tables typically contain fixed amounts of information and occupy a small-size storage, both the server and mobile terminals could afford to host a replication of them by following the publication/subscription model. That is, the tables and schema are published at the server side and subscribed by the SQL Server CE on the Pocket PC. Data updating could actually be performed for the mobile client and central server respectively. The final results are merged into the same replication on two devices via bi-directional data synchronization (merge replication). The synchronization operation is typically triggered programmatically after the user respondent has finished filling in data on a survey form and then continues for the next one.

“ActivityData” database instance also includes trip data collected via GPS receivers. The trace of one trip involved in reaching an activity site is stored in an individual trip file with the corresponding “Implement Activity ID” labeled as its name (iActivityID). As the trip data grow dynamically as time goes during the survey period, the Pocket PC can’t afford to keep a local replication of all these data in its local storage but can only maintain a temporary snapshot of the current trip log. Each trip log file will be remotely sent back to the central server via a FTP

module, also locally backed up into the temporary snapshots as current trip log. After the trip is accomplished and its data are transferred, the local snapshot will be deleted to free the storage space for other use. If any of the data transfer functions fail due to temporary network connection problem, the failed trip data will be cached for a later resubmission, until all the data submitting operations succeed.

#### **5.4 Mobile Usages of The Data Collection Terminal**

For the practical use of the data collection system with survey respondents, who may travels under various types of travel/transport modes, the data collection terminal is equipped with a small camera bag with an external GPS antenna attached on the shoulder strap. When the survey respondent is carrying the device in walk/bicycle mode and travel route tracked by the GPS receiver, the device would be put the package and connected to the external antenna for enhancing the accuracy of collected position data. If a vehicle is involved during the travel, ARKON multimedia PDA mount is used to hold the data collection terminal at a fixed and steady position close to windshield and front dashboard for better access of the satellite signals. Three options are available to mount the PDA in a customized way: Windshield pedestal installation, Console mount installation and vent mount installation. However, except the windshield pedestal installation option, all the others are semi-permanent in nature and difficult to remove in certain circumstances. Windshield pedestal, with the help of a suction disc, holds tight against the window after the locking lever is pushed down. The affixation is strong enough to carry a portable device with weight up to 10 pounds. The suction affixation can be easily removed by lifting the locking level thus the whole set of subsidiary equipment is pretty portable among the multiple vehicles that a survey respondent may have access to. In addition, the PDA cradle that holds the Pocket PC is DC powered and embedded with a build-in speaker. The cradle connects to the device via a USB to its serial cable. The audio output from the Pocket PC can be optionally boosted via a connection to the cradle's audio jack. Hence audio prompt/help of the survey won't be indulged in the noise of the traffic during the travel duration and the data collection terminal is less subject to the possible power drainage as charging is available in a long-journey in-car travel. Another

regular power supplement is also provided separately to the survey respondent to charge the device at home during night or in office during daytime.

## **6. SPECIAL ISSUES AND FUTURE DEVELOPMENT**

### **6.1 The Mapping Component**

The mapping component used in the data collection system is a customized version of ARCPAD (a mobile GIS product from ESRI) via VBscript. GDT (General Dynamic Street) data used has relatively small data size and accurate local road network reference. To avoid crowding the map display with loads of map symbols and speed up the map loading/refresh process, only road, county and institution data layers are selected to form the basis of local map presentation. The map display doesn't show with any annotation thus the survey respondent can only count on their familiarity with the local road network to identify their home or the potential activity locations. ESRI recently pushed out a complementary tool to ARCPAD with the name ARCPAD STREETMAP. It includes with itself with a compressed street database for the continental U.S.A. Additionally, it provides address geocoding (vice versa) and other convenient functions for navigation purposes.

Use of ARCPAD STREETMAP for the mapping component was also tested with the data collection system. It offers the following advantages compared to the raw ARCPAD as the mapping component:

- a). It compressed data layer offers rich local-features information. Particularly, it contains its own version textual annotations and varies their sizes in correspondence with the current map scale.
- b). Its compressed data size is considerably smaller than that of data prepared from GDT database via ARCVIEW.

In terms of performance of the two different versions of mapping components, an individual test run of both has been conducted and the following parameters are compared (Table 1):

Ideally, it will be better to use ARCPAD STREETMAP as the mapping component in our system, in spite of the fact that its memory requirement is demanding and its load-up time is considerably longer. After all, for a travel/activity survey, the crispy and easy-to-understand map display outweighs other factors as it directly affects the quality of collected spatial data.

Unfortunately, ARCPAD STREETMAP loads in its compressed data layer in its special way. The loading process fails when another Visual Basic program is running on the device (such as our survey program). This has obliterated the possibility of incorporating it into the system at current stage.

## **6.2 Data Upload and Speech Recognition**

AT&T wireless data service is used for uploading the data from the mobile data collection terminal—Pocket PC to the central data collection server. The activation fee is \$36 per device and monthly service fee costs \$39.99 under 20 megabytes limit. The whole data uploading process consists of two steps: 1) data is inserted into the local table storages for caching and survey program use; 2) data in the local database is synchronized with those in central data server and get uploaded. Step 1 costs trivial and only needs 5-8 seconds. However Step 2 is more time-consuming. A simple data upload session could take 30-90 seconds. For fulfilling the real-time data collection purposes, the ideal approach to handle data upload process would execute step 1 and 2 each time between form switches, thus the collected data is transferred back to the central data server immediately after they have been input by the survey respondents. However, the solution ends up with unbearable suspension after the survey respondent finishes the current survey form and wait to enter the next one. Concerned with the detriment it possibly induces to the real-time survey in terms of the survey fatigue effects, only local data storing procedures are inserted between form switches. The more time-intensive data synchronization process is

organized under one individual function button, which will be triggered by the survey respondent at a time convenient.

### **6.3 Next Generation Pocket PC and Future Development of the System**

The disadvantage of using IPAQ 3870 as the data collection terminal is that its battery is built-in in its shell thus irreplaceable. When the battery is not working any more, so is the device. It is not economic to use the model of IPAQ for a long-term data collection such as a longitudinal data collection practice with more than two or three years' time span. Fortunately, the manufacturers of the IPAQ/HP have realized the deficit. Newer model of IPAQ such as IPAQ H5450 comes with a user-replaceable/rechargeable battery. Alternating the use of two rechargeable batteries will greatly enhance the usage duration and lifetime of the device with less or none cumbersome supplementary powering equipments.

Another problem with the current speech-enabled survey interface is that the speech recognition capabilities being developed on the SCANSOFT speech recognition engine and SDK collides with SQL SERVER CE (the database technology we are using for storing data on the Pocket PC). The problem is being solved but in a very slow pace. The potential solution is the Microsoft's new operating system for the most recent mobile devices (Windows CE. Net). With a set of built-in system speech APIs, speech engine and grammar libraries, it would allow the speech capability built with without interfering with other software components. However, this demands the purchase of a newer model of equipments and has been hindered by our limited funding support.

## **7. CONCLUSIONS**

This research conceptualized and implemented a real-time system tool that facilitates the study of the dynamic linkages between the activity scheduling and execution process at an individual level. The survey methodology opens the opportunity for researchers to gather information on the

integral scheduling and activity execution process by means of empirical data collection and to model the relationship between them. This research attempt contributes to the progress of the current computer-assisted travel/activity survey practices from two perspectives: on one hand, schedule/travel/activity data is collected in real time which is similar to the traditional paper-pencil-based approach, but overcomes its deficits such as limited storage capacity and linear survey format; on the other hand, with the multi-modal interface designed for the mobile computing device, especially with the enhanced voice capabilities, the silent machine is endowed with its own personality and limited intelligence. Ideally it would be treated more equally as an experienced “human” interviewer by the survey respondents in their role interpretation but without arousing the concerns of privacy invasion. For our future research, the data provided by the system will be used for in-depth analysis of the interaction between scheduling and correlated activity execution in future modeling developments. At the current stage, we are conducting a pilot data collection study with the system and study the dynamic linkage between activity scheduling and associated execution with a nested logit modeling approach. It would be also interesting to compare instrument bias and survey burden brought by the system with traditional activity/travel data collection methods. Further improvement on duration and reliability of the system potentially endows the activity/travel researchers with a powerful tool to enlarge the data bases for the longitudinal trends of activity/travel pattern changes.

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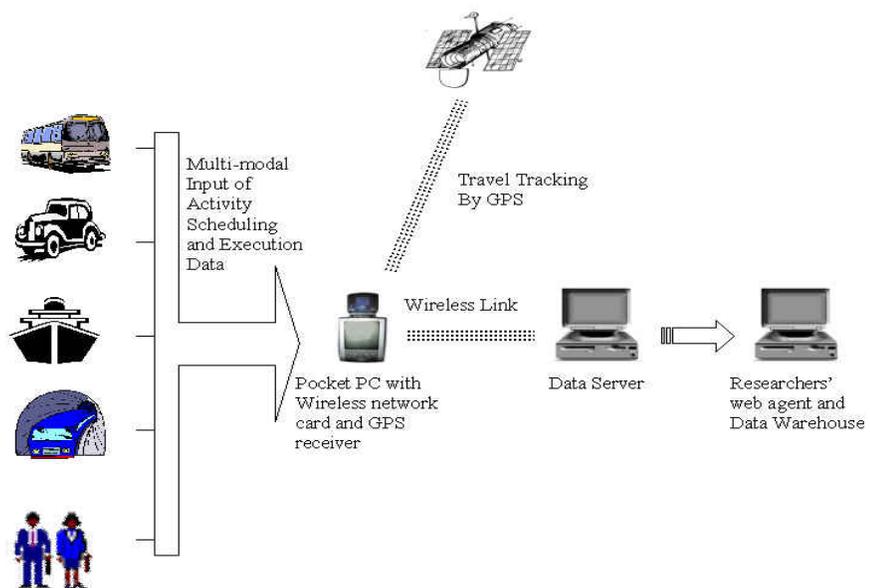
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**Figure 1. System Composition**



**Figure 2: Start-up Form of Activity  
Scheduling and Implementation  
Survey**

**Figure 3: Personal Demographic  
Information**

**Start Up** 9:03

## Activity Scheduling and Implementation Survey

- ? 1. Personal Info and Week Schedule
- ? 2. Schedule Activities or Refine the Schedules
- ? 3. Trace Activity Implementation
- ? 4. Answer questions related to unfulfilled activities in schedule

? Upload Data ? 5. Exit Survey

**Option**

**Personal Info** 3:10

Last Name:

First Name:

Sex:  Male  Female

Married:  Yes  No

Age:

Do you have a driver's license?  Yes  No

Education Level:

Monthly income, if any:

Vehicle Accessibility: (Number of Vehicles)

Finish It Later! BACK NEXT

**Figure 4: Address/contact info and Transport Modes the Respondent Usually Uses**

The screenshot shows the 'Initial Interview' window with a clock at 10:25. The main content area is titled 'Current Address and Contact Info' and contains the following fields:

- Street Address: [Text Input]
- City: [Text Input]
- State: California (dropdown menu) | Zip: [Text Input]
- Phone: [xxx] -- [xxx] -- [xxxx] (masked input)
- Email: [Text Input]

Below the address fields is a section titled 'Please check the transportation modes you use'. It includes a sidebar on the left with the text 'Identify the Address Location on Map' and a list of transport modes:

- Walk
- Carpool with other
- Vanpool

At the bottom of the window are three buttons: 'Finish It Later!', 'BACK', and 'NEXT'.

**Figure 5: Select the Types of Activities with High Repetition Rate**

The screenshot shows the 'Activity Selection--Initi' window with a clock at 6:23. It features an 'Important Notes' section at the top:

Please check all the activities that you typically does (at least once a month) under the appropriate category (shown on the tab header). The activities currently checked are defaults.

Below the notes is a tabbed interface with two tabs: 'Eat/Sleep/Personal hygiene' and 'Househol'. The 'Househol' tab is active, showing a list of activities with checkboxes:

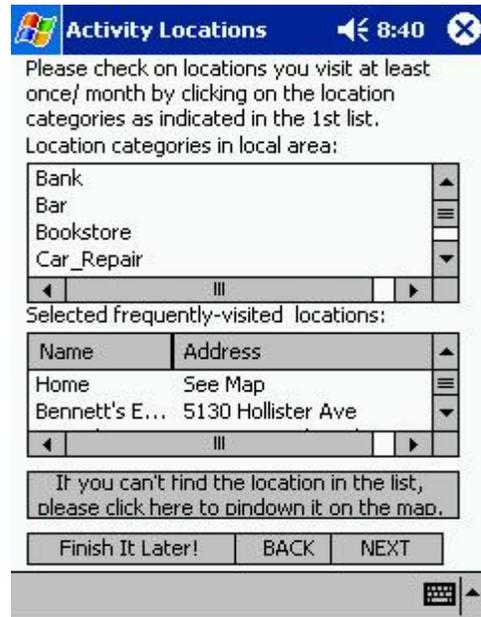
- Dining out at restaurant
- Meal [at home or work]
- Night sleep
- Snack
- Wash/dress/pack

At the bottom of the window are three buttons: 'Finish It Later!', 'BACK', and 'NEXT'.

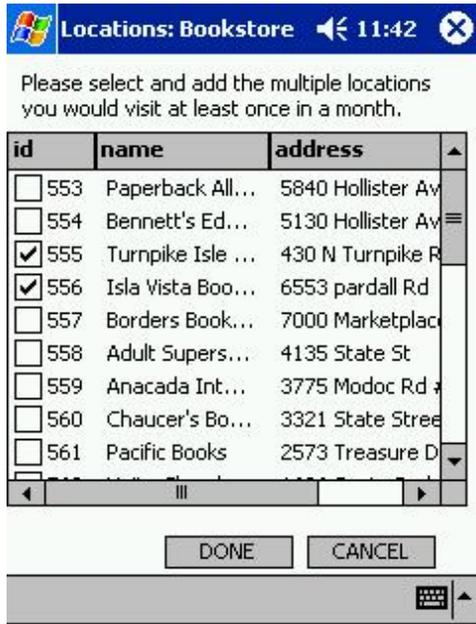
**Figure 6: Add The Types of Activities that Are Not Included in The Previous List**



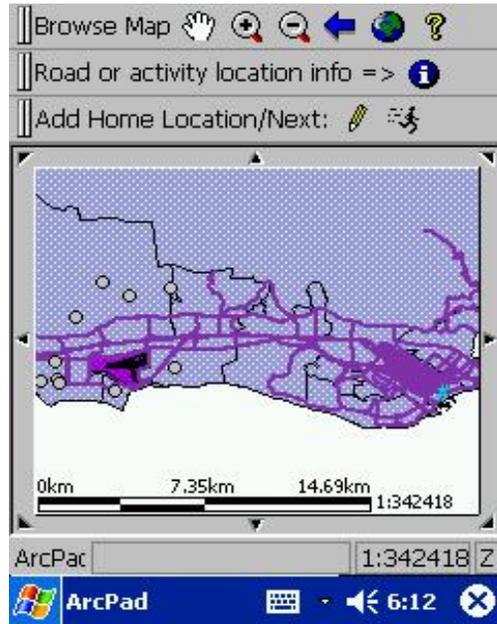
**Figure 7: Select Frequently Visited Activity Locations**



**Figure 8: The List of Bookstores in the Local On-line Yellow Page**



**Figure 9: Add home/activity Location via the Built-in GIS (ARCPAD)**

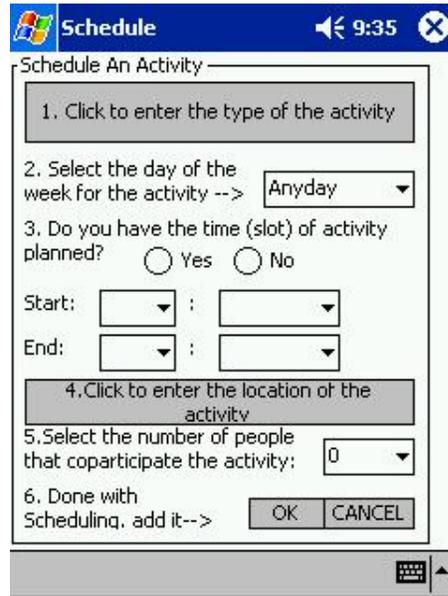


**Figure 10: Set Up the Week**

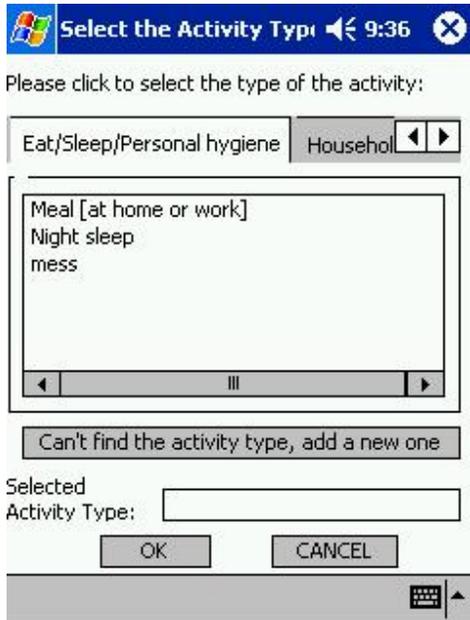
**Schedule**



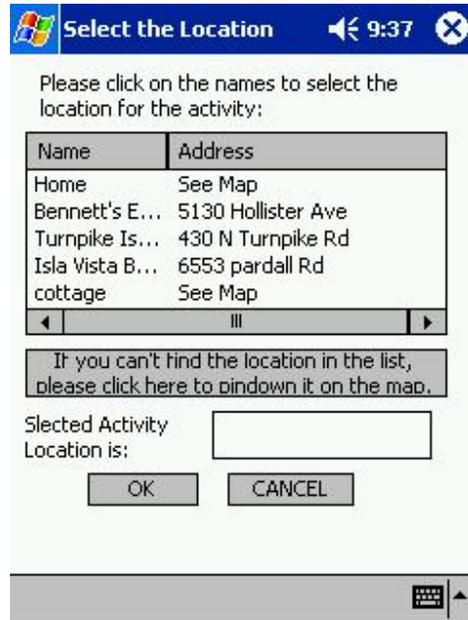
**Figure 11: Schedule an Activity**



**Figure 12: Select the Planned Activity Type**



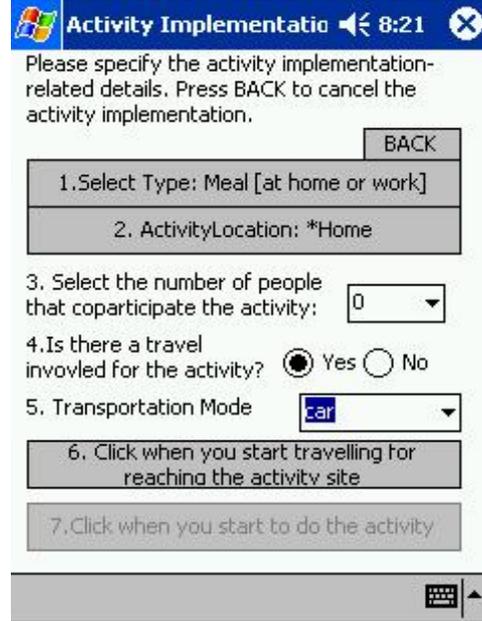
**Figure 13. Select the Planned Activity Location**



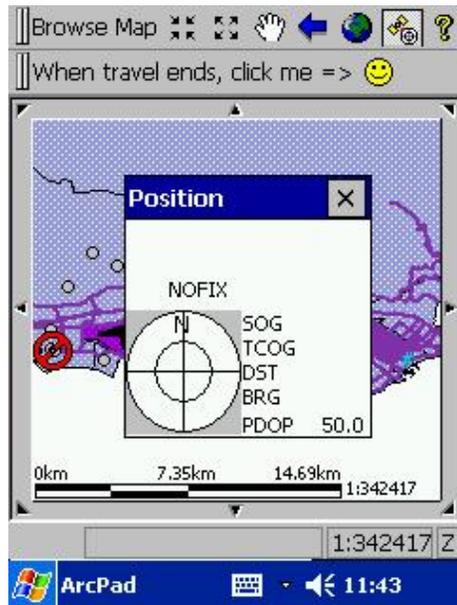
**Figure 14: Schedule Activities or Refine Schedules At Real Time**



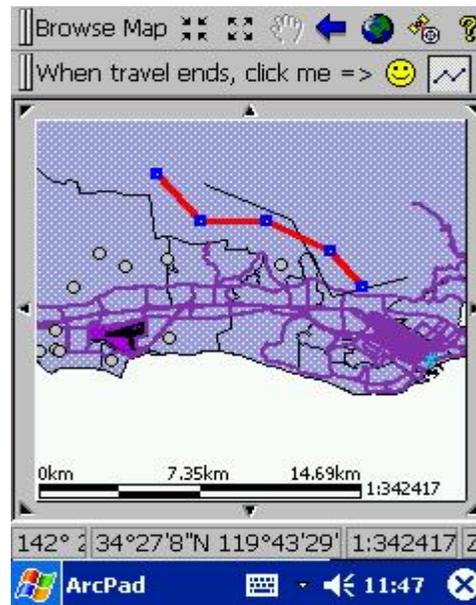
**Figure 15: Trace Activity Implementation at Real Time**



**Figure 16: Tracing Travel Derived for Reaching the Activity Site**



**Figure 17: Draw the Travel Route with “Draw Route Tool” when Most of Sampled GPS Points are Invalid**



**Figure 18: Activity-related Questions**      **Figure 19: Start-up Form with Activity Duration Timer On**

**Activity-related Quest** 11:49

1. How is the weather condition?

2. How is the traffic condition when you travel?

3. If you received a service at the activity site, please indicate the time slot that the service is available.  
 Start:  :   
 End:  :

4. Does any co-participant of the activity withdraw from it?  Yes  No

5. Given a scale from 1 - 5, please indicate the priority of the activity (with 1 as the highest, and 5 as lowest).  **DONE**

**Start Up** 8:50

*Activity Scheduling and Implementation Survey*

- ? 1. Personal Info and Week Schedule
- ? 2. Schedule Activities or Refine the Schedules
- ? 3. Trace Activity Implementation
- ? 4. Answer questions related to unfulfilled activities in schedule

Activity ongoing.  
 Duration by now: 00:19:58 **Done with the activity ==>**

- ? Upload Data
- ? 5. Exit Survey

**Option**

**Figure 20: Link Activity Schedule to the Actual Implementation**

**Relate to Schedule** 11:41

If the activity has ever been scheduled, please select the schedule that relates to the activity you are going to do by clicking, otherwise, just press continue.

If the related schedule info has been forgotten to input, add it here.

Anyday Monday Tuesday Wed

Activity	Start	End	Location
Phone/e...	N/A	N/A	*Home

Fri 7/4/03

Back Next

**Figure 21: How the Activity Implementation Conforms to the Schedule**

**Activity-related quest** 12:45

Please indicate how the actual implementation of the activity conforms to your schedule:

- Activity starts —
  - as scheduled
  - early
  - late
- Activity duration is —
  - as scheduled
  - shorter than scheduled
  - longer than scheduled
- Activity location —
  - stays as scheduled
  - was changed to another location

NEXT

**Figure 22: Questions Related to Unfulfilled Activities**

Activity-related Quest ◀ 11:52 ✕

It seems that the activity < Meal [at home or work] > you have scheduled to do at Bennett's Educational Material on Wednesday wasn't implemented. Please answer the following questions related to the missed schedule:

1. Has the activity been forgotten to do?  
 Yes  No

2. Did lack of sufficient conditions prevent you from performing the activity as scheduled?  
 Yes  No

ANSWER IT LATER    NEXT

**Figure 23: Questions Related to Unfulfilled Activities**

Activity-related Quest ◀ 11:55 ✕

1. How is the weather condition back then?  
[Dropdown menu]

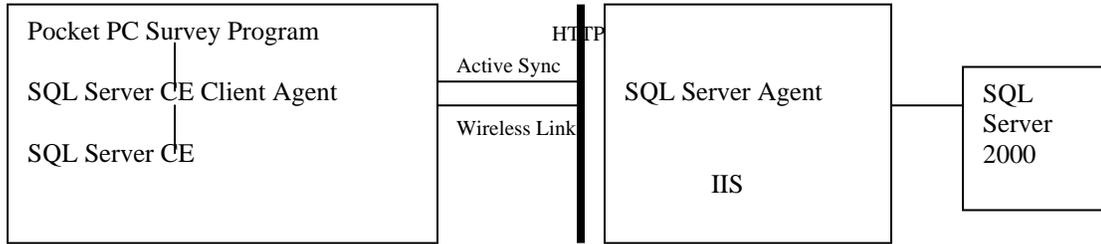
2. What do you know about the traffic conditions back then (from your information channel or your believe-in)?  
[Dropdown menu]

3. If you could have received a service at the activity site, please indicate the time slot that the service is available.  
Start: [Dropdown] : [Dropdown]  
End: [Dropdown] : [Dropdown]

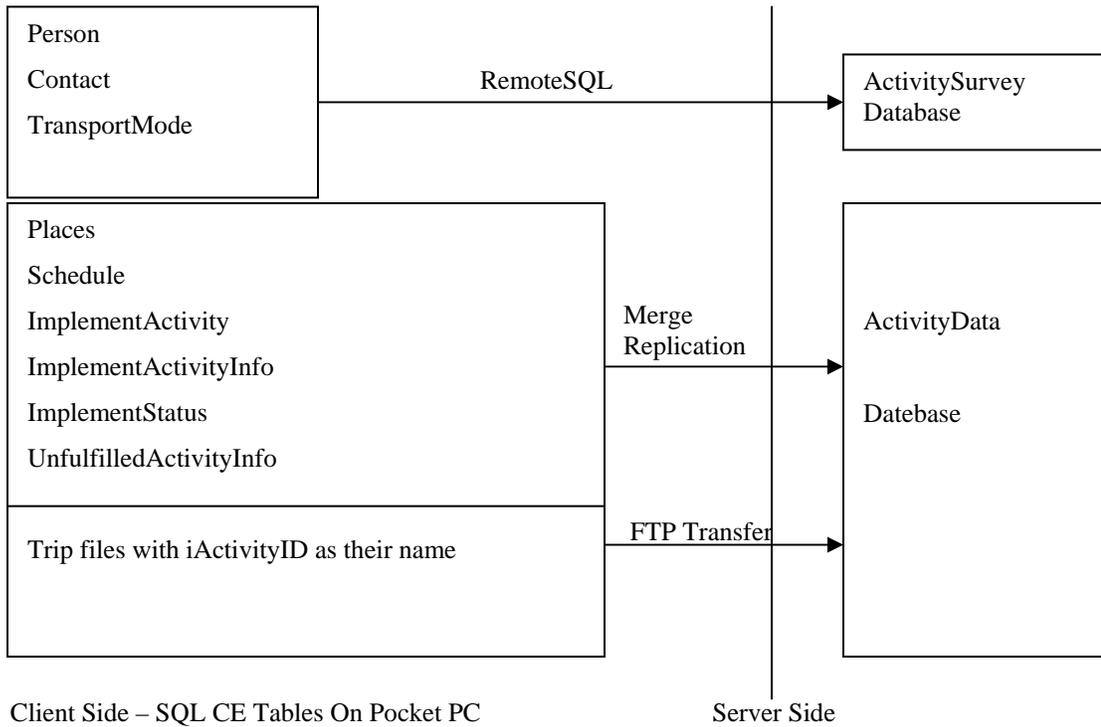
4. Does any co-participant of the activity withdraw from it?  Yes  No

5. Given a scale from 1 - 5, please indicate the priority of the activity (with 1 as the highest, and 5 as lowest). [Dropdown]    DONE

**Figure 24: Database Infrastructure (Adapted from SQL Server CE online Book)**



**Figure 25: Illustration of Data Organization and Transmission**



**Table 1. Performance Comparison of ARCPAD and ARCPAD STREETMAP**

	ARCPAD	ARCPAD STREETMAP
Load Up Time	7-10 seconds	25-35 seconds
Memory Use	4 megabytes	9 megabytes
Map Refresh Time	3-6 seconds	2-3 seconds