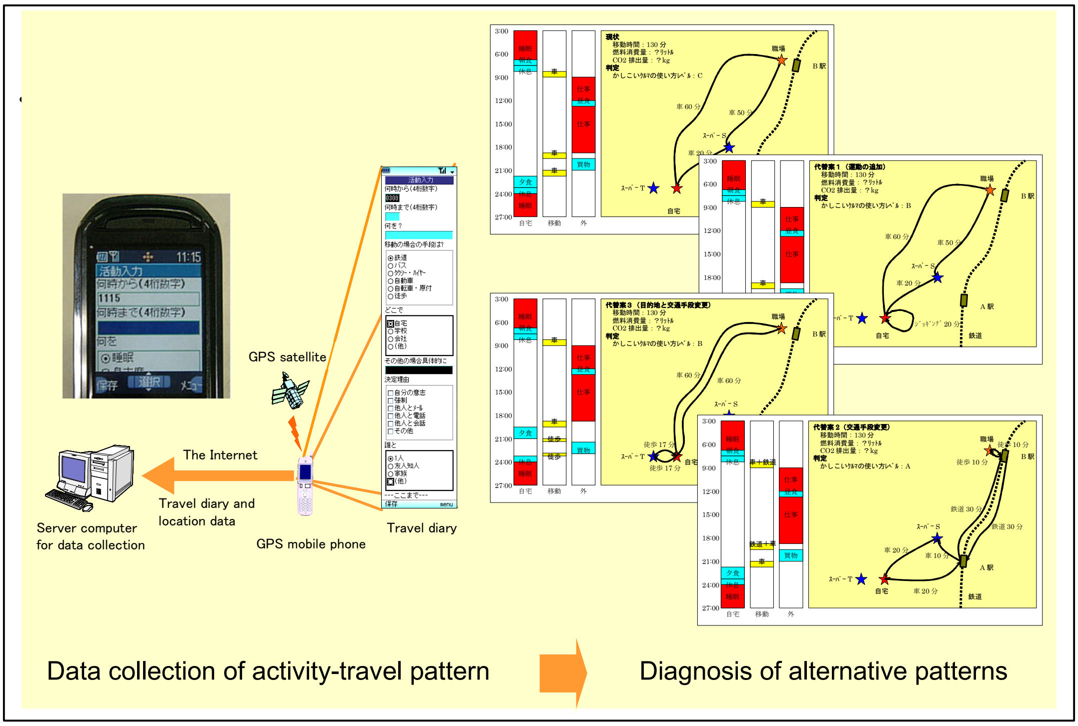

Internet GIS-Based Activity-Travel Simulator for Investigating Alternative Activity-Travel Patterns

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Internet GIS-Based Activity-Travel Simulator for Investigating Alternative Activity-Travel Patterns

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Abstract

This paper reports the development of an integrated system for data collection, analysis, representation and evaluation of individual activity-travel patterns, using GPS mobile phones and Web GIS technologies, and its application to travel feedback programs. A GPS mobile-phone-based survey system was developed to collect information on travel diaries and travel routes, which were used as an input to the Internet GIS-based activity-travel simulator. The simulator provided information on diagnostic indices and spatial movement of the current travel pattern and alternative travel patterns of different travel modes. Participants were able to compare the current travel pattern with alternative ones on the Web browser, investigating diagnostic indices and spatial movements on a map. The system was applied to the travel feedback program for the employees working in the Osaka Prefectural Government. The system, as a new communication tool of the travel feedback program, contributed to improving the participants' attitudes and to changing travel behavior towards decreasing car-use.

Keywords

Internet GIS, Activity-Travel Simulator, GPS mobile phone, Travel Feedback Program

Preferred Citation

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1. Introduction

For sustainable cities, reducing car-use has been a main target in transportation policy. Transportation demand management (TDM) measures such as Park & Ride and carpooling have been introduced for the last two decades. However, these measures do not work effectively unless travelers themselves identify their car-use has brought about a lot of problems against sustainable cities. In this context, encouraging travelers to become involved in environmentally friendly travel patterns is one of the effective and promising policy measures to reduce car-use. Jones (2003) called such approaches soft measures in mobility management. The effectiveness of the approaches has been demonstrated by previous research, e.g., Individualized Marketing (Brög, 1998), Travel Smart (Department of Transport, Western Australia, 2000), Travel Blending (Rose and Ampt, 2001) and the Travel Feedback Program (TFP) (Taniguchi *et al*., 2003). These behavior modification programs are referred to as *travel feedback programs* (Fujii and Taniguchi, 2005). In these programs, the first step is obtaining information on travel diaries from participants to diagnose their travel patterns. Next, the programs provide the participants with information on the CO_2 emissions they produced, and on public transport as an alternative mode, and/or advise how to reduce car-use based on their current travel patterns. Some programs ask the participants to make behavioral plans (Fujii and Taniguchi, 2005). The existent research in western countries reports that aggregate car-use of the participants reduced by about 10-20% after participation in the programs. Also in Japan, an interest in these programs has rapidly been increasing. In particular, the Travel Feedback Program has been implemented in a lot of cities (Japan Society of Civil Engineers, 2005).

However, the programs spend many human and financial resources at each stage as collecting participants' travel diaries using paper-based questionnaire sheets, analyzing them and advising the participants to use car more environmentally friendly. Data accuracy of travel diaries collected using paper-based questionnaire sheets has been a problem. It takes much time and money to generate individualized alternative activity-travel patterns of more environmentally friendly for each participant. Daito *et al.* (2005) developed the Travel Feedback Program system using Web technologies (WEB TFP), which collects travel diaries from participants on the Web browser. This system alleviates spatial constraints in implementing the program. It has been applied especially to the workplace-based travel feedback program. For example, more than 700 employees in a company working at 13 offices located in several parts of Japan participated in the WEB TFP (Ozawa *et al*., 2006). However, the WEB TFP system does not collect spatial information on travel patterns and not provide the participants with it on the Web browser. Not only temporal information of travel patterns but also spatial information of them is very useful for individuals to understand and investigate their current and alternative travel patterns in urban space (e.g., Jones 1982; Jones *et al*., 1983; Ohmori *et al*., 2005). To collect more accurate and detailed information on individual travel patterns, positioning technologies such as Global Positioning System (GPS) and Global System for Mobile Communications (GSM) can be applied (e.g., Murakami and Wagner, 1999; Ohmori *et al*., 2000; Asakura and Hato, 2004). In addition, Geographic Information System (GIS) is a very effective tool for the management, analysis and representation of spatial elements of the transportation network and individual travel patterns. There has been some research to explore the possibility of developing integrated models of activity-travel patterns and GIS (e.g., Golledge *et al*., 1994; Kwan, 1997).

The authors have been developing GIS-based activity-travel simulators, which can generate alternative activity-travel patterns and represent them on GIS (Ohmori *et al*., 2005). There is possibility to apply this system to travel feedback programs as a communication tool for interactive diagnosis of individual/household activity-travel patterns. This paper reports the development of an integrated system for data collection, analysis, representation and evaluation of individual activity-travel patterns, using GPS mobile phones and Web-GIS technologies, which is named *i*SMAP (Internet-based Simulation Model for Activity Planning), and its application to the travel feedback programs. The system developed in this study does not recommend which travel pattern is better for environment or individual health, but the participants themselves can investigate alternative activity-travel patterns on the Web browser.

2. Development of the System

2.1. GPS Mobile-Phone-Based Travel Diary Survey System

Usually in the travel feedback programs, paper-based questionnaire sheets or Web-based questionnaires have been used to collect participants' travel diaries. In this study, a GPS mobile-phone-based travel diary survey system was developed to collect information on individual travel patterns, based on the authors' previous study (Ohmori *et al*., 2005). The advantages of this system are considered as follows:

- to directly collect electronic data on travel diaries and to transmit the data through a wireless network (GSM network and the Internet);
- to automatically collect positional data at a regular time interval to specify origins/destinations and travel routes; and
- to reduce the survey costs of time and money both for distribution and collection of survey materials, and for transmitting, editing and inputting the collected data.

The software programmed in Java language works on the mobile phone devices with GPS installed of "*au*" by KDDI Corporation, for entering information on travel diaries. The "*au*" employs "gpsOne", which is called the Assisted GPS (see KDDI website). It calculates the current position using not only GPS but also information on received signals from multiple base stations to which the mobile phone device is connected. Therefore, positional data can be collected even if GPS is not available or it is carried in a coat or jacket pocket. The software is downloaded via the wireless network and installed in the mobile phone. Positional data (longitude and latitude) are automatically collected at regular time intervals. Travel diaries and GPS tracking data are transmitted to a server computer. Participants just carry the GPS mobile phone, and push some buttons whenever they leave origins and arrive at destinations. They can enter information on trip purposes (commute, business, going home, private, shopping/eating out, escort, and other) and (main and access/egress) travel modes into the GPS mobile-phone-based survey system. The data collection system was designed to impose the minimum respondent burden on the participants.

2.2. Internet GIS-Based Interactive Travel Feedback System

MapInfo MapXtreme software was used for the Internet GIS-based interactive activity-travel simulator, *i*SMAP. By using the Web GIS software, it becomes very easy to manage GIS data and represent spatial information in the Web environment (see Aono *et al*., 2004; Aono *et al*., 2006). Programs of data management and representation on the Web browser were written in VBScript. When this research was launched into, the authors had thought that it would be better for the participants to access to the program website from their home or office once a day. The system consists of the following two parts:

- completing the travel diaries and spatial information on travel patterns; and
- simulating alternative travel patterns.

2.2.1. Completing Travel Diaries and Spatial Information on Travel Patterns

On the Web browser, one-day travel diary and travel trajectory collected by the GPS mobile-phone system are represented in spatial and temporal dimensions (see *"the current travel pattern*" of Figure 1). GIS raster data of ProAtlas map in Osaka area were used to easily identify urban space and individual spatial travel patterns. Also several diagnostic indices about the day's travel pattern such as travel times, travel distances, travel costs by each travel mode, the total daily CO_2 emissions and the total daily calorie consumptions are calculated based on the travel data and represented on the Web browser. The participants can reflect their current travel patterns on that day investigating the represented information.

The names of origins and destinations can be directly entered on the Web browser. When the participants did not enter information on trip purposes and travel modes or entered incorrect information into the GPS mobile-phone-based survey system, they can enter or correct the information on the Web browser. Some trips might be missed or incorrectly represented in the travel diary, because they forgot to push buttons of the GPS mobile phone when leaving origins or arriving at destinations. They can modify the travel diary by deleting and adding trips on the Web browser. Spatial information on origins and destinations can be also easily modified on the Web GIS.

2.2.2. Simulating Alternative Travel Patterns

Alternative travel patterns of different travel modes are generated on condition that locations and start times of out-of-home activities engaged in on the day are fixed. The participants can change travel modes of any trips of the current travel patterns to alternative ones. Alternative main modes are train, bus, car, taxi, bicycle and walk. A GIS database of railway network in Osaka area, including 1,419 railway stations in 22 railway companies, was used to calculate travel times and travel routes by train. Travel time by train between an origin and a destination is that of the route of the minimum travel time using the nearest railway stations from the origin/destination. A database of travel fee by train was originally prepared. We did not prepare bus network data. If the participants choose train or bus as a main mode, they also choose access/egress modes. Available access/egress modes to/from the railway stations are bus, car, taxi, bicycle and walk. Travel routes of alternative patterns are represented on the GIS map. When the alternative mode is train, the travel route is represented by polylines connected with intermediate stations. Whereas the alternative mode is not the train, the travel route is the same as the current trip. In "*the alternative travel pattern No.1*" of Figure 1, a change in travel routes of some trips from car to subway is represented. Information on alternative travel patterns is added below the current travel pattern successively on the Web browser. Participants can compare the current travel pattern with alternative ones, investigating the spatial movements and diagnostic indices of the travel patterns, and are asked which pattern they prefer. In the last stage, the system asks the participants which diagnostic indices such as travel times, travel costs, CO_2 emissions and calorie consumptions affected their preference, and the constraints of their trips.

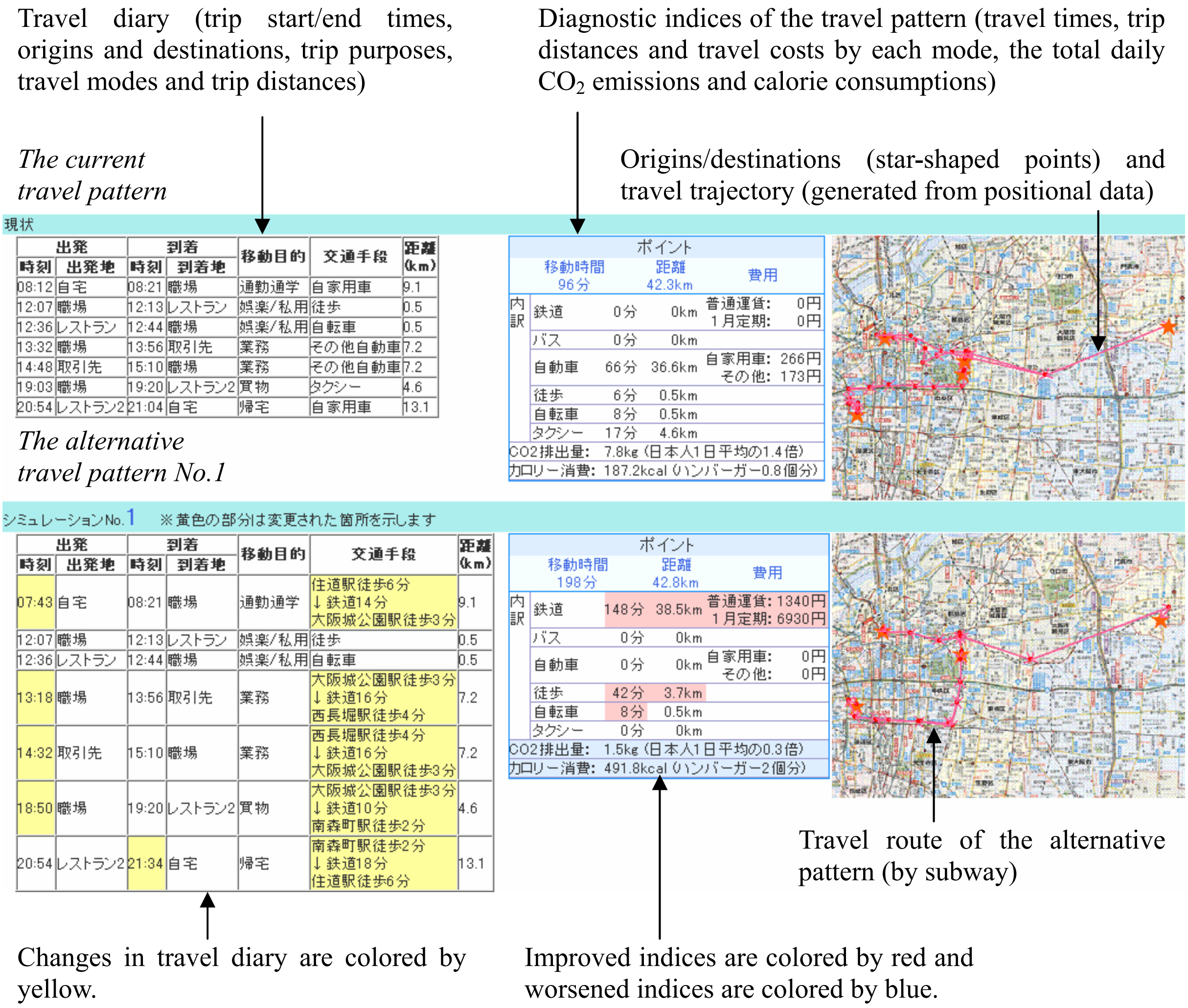


Figure 1 Snapshot of the *i*SMAP (Representation of the Current Travel Pattern of a Day and an Alternative Travel Pattern)

3. Application of the System to the Travel Feedback Program in Osaka

To investigate how the system can work as a communication tool of the travel feedback program and to identify problems occurring in its practical use, a pilot study was conducted for the participants working at the Department of Civil Engineers, in the Osaka Prefectural Government, in November to December 2005. As a rule, the office prohibits its employees to commute by car. Figure 2 shows a flowchart of the travel feedback program. The program was basically implemented using the WEB TFP system (Daito *et al*., 2005).

In the first stage of the program, a questionnaire survey was conducted for obtaining information on daily car-use, attitude for transport and environment and habitual intensity, and for screening the sample. Questions about attitude for transport and environment were to ask answers of five-point scale for the following five questions: “Do you think car-use is not good for your health?”, “Do you think car-use is not good for environment?”, “Do you think it is better to reduce car-use?”, “Do you think reducing your car-use is difficult?” and “Do you think you will try to reduce your car-use?”. Questions about habitual intensity were to ask which travel mode they use when traveling for a total of 10 trip purposes, e.g., visiting friend’s house, business, going to convenience stores, shopping clothes, etc.

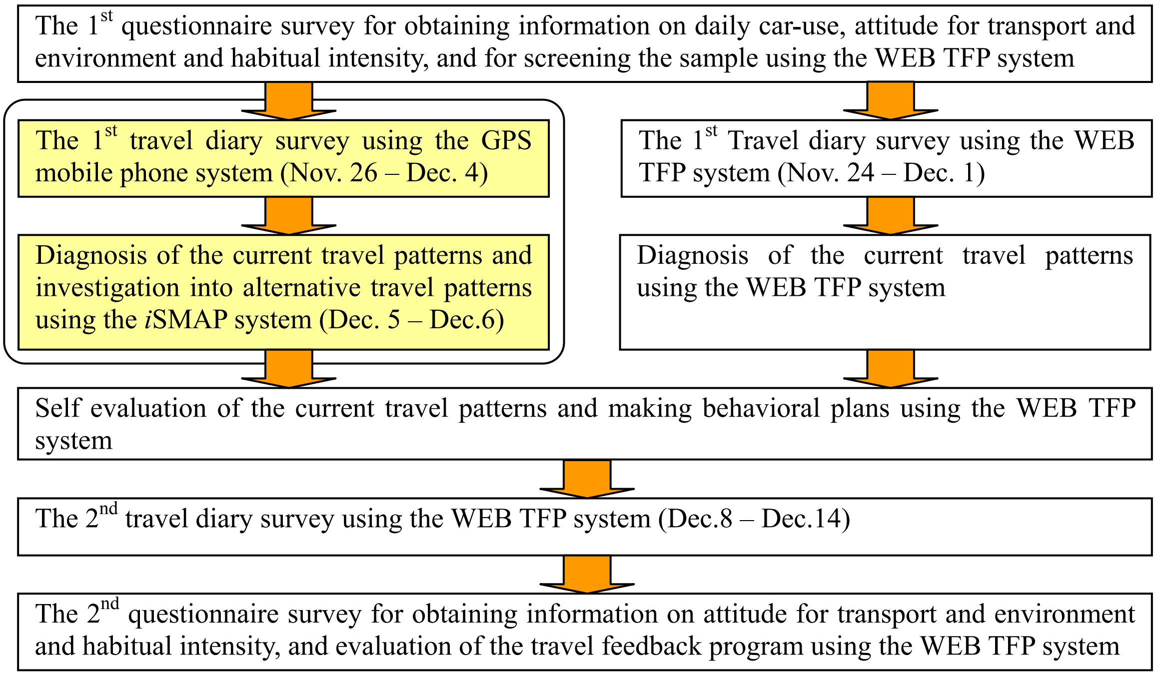


Figure 2 Flowchart of the Travel Feedback Program in the Osaka Prefectural Government

As shown in Figure 2, two different systems (the *i*SMAP and the WEB TFP) were used for communication tools in the diagnosis step. The WEB TFP system required participants to record two-weekend-day travel diaries (trip start/end times, destinations, trip purposes and travel times by each travel mode) on the Web browser and showed diagnostic indices of the current travel pattern such as total travel time, percentage of car-use, fuel consumptions, CO_2 emissions and calorie consumptions. A total of 70 employees, who had a driving license and daily used a car, were recruited as the participants to the program. Twenty of them participated in the program using *i*SMAP and the rest 50 employees participated in the program using the WEB TFP system. All the participants were males and 30’s to 50’s years old.

The GPS mobile phones pre-installed with the software for travel diary data collection were distributed to the participants of the *i*SMAP group. Ten of them were explained in face-to-face by the instructor how to use the mobile phone in the 1st travel diary survey. The participants were asked to carry the mobile phone and record travel diaries on a total of 4 weekend days during Saturday, November 26 to Sunday, December 4, 2005. They were asked to charge the mobile phone while in their home and office. They were asked to power the mobile phone on and push buttons when they start trips, and enter information on trip purposes and travel modes if possible. Positional information on longitude and latitude was collected every 2 minutes. When arriving at destinations, they were asked to push buttons and power it off. This process saved the battery consumption of the mobile phone.

Immediately after the 1st travel diary survey, on December 5 or 6, the participants of the *i*SMAP group participated in a face-to-face interview with the instructors using the *i*SMAP at the office of the Department of Civil Engineers, in the Osaka Prefectural Government. Two laptop computers with the Internet access were prepared for the interviewing survey. At the beginning, the authors had intended to use the system as a self-operating system. However, this was the first trial to apply it to the travel feedback program and problems might possibly have occurred in self-operating the system. Therefore, we decided that the instructor supported to operate the system in face-to-face interviewing.

First, the instructor inputted the participant's ID number and password, and selected a day out of the 4 weekend days. Then the day's travel diaries and travel route on GIS map appeared. The participants entered the names of trip start/end locations on the Web browser. As for the trips of which they did not enter the whole information, the participants were asked to enter the rest information into the Web browser. Diagnostic indices calculated based on the travel diary were represented: travel times, travel distances and travel costs by travel mode, and the total CO_2 emissions as an index of environment and the total calorie consumptions as an index of health in the day. Next, the interviewer asked the participant, "Could you change travel modes in any trips?" The system showed information on an alternative travel pattern on the Web browser below the current pattern, if he changed travel modes. The participant identified the changes in spatial pattern and difference of diagnostic indices between before and after the mode change. This process was repeated until the participant considered that he had no more alternative patterns. Finally, he was asked, "Which travel pattern do you prefer, the current travel pattern or one of the alternative patterns?" and "Which diagnostic indices affected your preference?" If he preferred the current travel pattern, he was asked to choose the reasons why he could not prefer the alternative travel pattern from a list, e.g. problems in access/egress, frequency of public transport, luggage, weather, etc. It took about 30 minutes for a participant to complete the interview.

After the interview, the 2nd travel diary survey was conducted using the WEB TFP system on weekend days on December 8 to December 14. Lastly, the 2nd questionnaire survey was conducted for obtaining information on attitude for transport and environment, and evaluation of the travel feedback program.

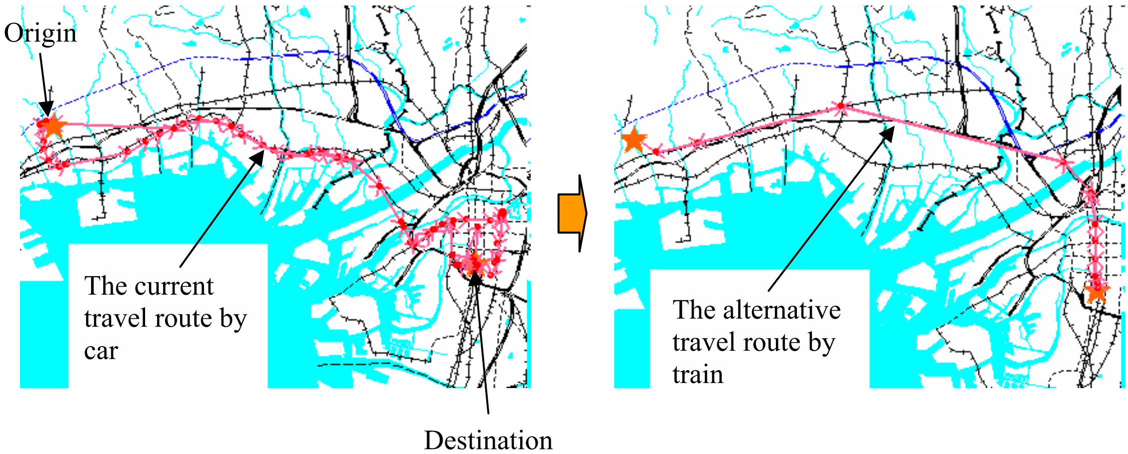
4. Results of the Application

4.1. Completing Travel Diaries

A total of 30 daily travel diaries of 20 participants were confirmed in the interview. About 20% of the participants did not enter the information on trip purposes and travel modes in the GPS mobile-phone-based survey system. Some trips were not recorded correctly. In a total of 13 trips, the participants forgot to push buttons of the mobile phone when leaving origins and/or arriving at destinations. On the contrary, a total of 6 trips were recorded by mistake when they did not make trips. The mobile phone exhausted the battery during trips in a total of 11 days. Multiple trips were sometimes consolidated into one trip. In advance of the interview for investigating travel patterns, the surveyor checked these trips of incomplete information. In the face-to-face interview, it took nearly 30 minutes in average to modify the trip information and to complete two-day travel diaries for one participant. Another reason of taking much time was that laptop PCs with the Internet access by PHS (Personal Handyphone System) of which the transmission speed was relatively slow (256kbps and 32kbps) was used.

4.2. Simulation of Alternative Travel Patterns

For 20 participants, alternative travel patterns were investigated for a total of 24 daily travel patterns of 17 participants. Three participants were not able to use other travel modes than car, because their trip destinations were closer to their home than to any railway stations. Seventeen of the 24 simulated travel patterns were the changes from car to train. The alternative travel patterns were preferred to the current pattern in 7 of them. The rest of the simulated patterns were the changes in travel mode from car to bicycle, car to bicycle and taxi, bicycle to walk, etc. It took less than 5 minutes to investigate at most two-day travel patterns for one participant. Figure 3 shows an example that a participant preferred the alternative pattern with mode change from car to train to the current pattern.



The current travel pattern: two trips by car	The alternative travel pattern: two trips by train
Total travel time: 230 min.	Total travel time: 148 min.
CO_2 emissions: 21.8kg	CO_2 emissions: 2.7kg
Calorie consumptions: 389.7kcal	Calorie consumptions: 330.4kcal

Figure 3 An Example that a Participant Preferred the Alternative Pattern with Mode Change from Car to Train to the Current Pattern

4.3. Changes in Attitude and Travel Behavior before and after the Travel Feedback Program

In this section, changes in attitude and travel behavior before and after participating in the travel feedback program are summarized and compared between the *i*SMAP group and the WEB TFP group. The analysis used the data collected in the 1st and 2nd questionnaire surveys for asking attitude and habitual intensity and the 1st and 2nd travel diary surveys of both groups. Complete datasets were obtained from a total of 13 participants in the *i*SMAP group and 50 in the WEB TFP group.

4.3.1. Changes in Attitude towards Transport and Environment

As for habitual intensity, the percentage the participants answered to use car for a total of 10 trip purposes decreased at almost the same rate in both groups (about 40% to 30%). In both groups, attitudes towards transport and environment were improved, except for the question, "Do you think car-use is not good for environment?". The reason could be that some of them did not realize the volume of CO_2 emissions. The percentage that they answered "Yes" to the question, "Do you think reducing your car-use is difficult?", especially decreased more in the *i*SMAP group. This result suggests that the participants were able to identify the changes of travel patterns more concretely and realistically using *i*SMAP system.

4.3.2. Changes in Travel Behavior

In the *i*SMAP group, the numbers of all trips and car trips, in average, did not change between the 1st and 2nd travel diary surveys, whereas the total travel time by car decreased by 16%. Besides, the number of walk trips decreased by 78% and the numbers of train and bus trips increased by 100%. Also the total travel time by train and bus increased by more than 100%. On the other hand, both the number of all trips and the total travel time decreased by 9% and 22% respectively. This result indicates that the *i*SMAP system emphasized and promoted public transport use. Then, we analyzed the relationships between individual characteristics (distance between their home and railway stations, preference in simulating alternative patterns, etc.) and modal shift to public transport. However, significant relationships were not found from the analyses. Especially in travel patterns not including shopping trips (without luggage), car-use reduced more in the *i*SMAP group than in the WEB TFP group.

4.4. Participants' Evaluation of the System

This section describes the participants' evaluation of the system based on the analysis of the data collected in the 2nd questionnaire survey after the feedback program. As for the GPS mobile-phone-based travel diary survey system, 54% of the participants were imposed (a little) burden. However, all of the participants answered that operating the mobile phone was (relatively) easy. As for the *i*SMAP system, more than 70% of the participants answered that it was easy to understand the spatial elements of their travel patterns on a map. Some participants gave opinions such as "The speed of representing spatial travel patterns on a map was very slow", "I wanted to change the scale of the map", "I wanted to do the diagnosis process on my PC". Most participants answered that the simulation process (77%) and diagnostic indices (64%) were easy to understand. However, one of the participants answered, "I wanted to see not only information on environmental issues but also that on economic issues", "I wanted to compare travel route, cost and time between the current and alternative travel patterns". These answers indicate that he did not correctly understand the information on the Web browser. It needs improvement of representation in a more understandable way. Some of them answered, "I need information of alternative routes of less travel time reflecting congestion."

5. Conclusion

This paper described the development of an integrated system for data collection, analysis, representation and evaluation of individual activity-travel patterns; the GPS mobile-phone-based travel diary survey system and the Web GIS-based activity-travel simulator, *i*SMAP. Information on travel diaries was collected using the Java application working in GPS-mobile phones and could be also modified in the Web browser. The system generated alternative travel patterns with diagnostic indices representing the travel pattern. We applied it to the travel feedback program for employees working in the Osaka Prefectural Government as a pilot study. The feedback program with the *i*SMAP contributed to improving the participants' attitudes towards reducing car-use. Travel distances by car decreased more and public transport use increased more in the *i*SMAP group than in the WEB TFP group after participating in the travel feedback program. This could be due to the function that the participants could interactively investigate individualized alternative travel patterns considering spatial information and diagnostic indices.

For the future research, the process of completing travel diaries should be improved, because it took much time to modify and complete the travel diaries collected with the GPS mobile-phone-based survey system in the pilot study. The *i*SMAP can be applied to any participants living in any cities where GIS database of transport network is available. In this study, the system was applied to weekend days' travel patterns, because the participants were prohibited from commuting by car. We are planning to apply the system to commuters by car and to examine the possibilities of behavioral change to environmentally friendly travel modes. At present, since generated alternative activity-travel patterns are conditioned with fixed locations and start times of the current activities, only changes in travel modes are examined. We try to improve the system to generate more flexible alternative travel patterns, incorporating not only travel modes but also locations, time of day and the sequence of the activities. Other diagnostic indices such as the volume of environmental exposure to air pollution such as NO_x and PM would be useful for self diagnosis of travel patterns.

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