An Empirical Study of Additional Stopover Behaviors of Car Tourists Affecting by Traffic Congestion Information Using Mobile Probe Data

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***Abstract*—Car tourists may make some additional stopovers for sightseeing, meal, shopping, or leisure activities which is not originally planned, to avoid becoming involved in the traffic congestion occurring on the homeward route. The objective of this paper is to examine whether this induced stopover behavior exists and to empirically analyze the tendency of additional stopovers by departure time periods for homeward trip and level of traffic congestions. An analysis of route search data and GPS travel trajectory data collected by mobile car navigation application is conducted. The study results show car tourists tend to have additional stopovers when the departure time for homeward trip is early, and differences in the tendency of additional stopovers by congestion levels are observed, implying the impact of traffic congestion on additional stopover behaviors to some extent. The study results suggest the possibility of promoting additional stopovers in tourism areas for congestion avoidance by providing predicted near future traffic congestion and surrounding tourism information, which is beneficial to both tourism promotion and traffic congestion mitigation.**

***Index Terms*—additional stopover, traffic congestion, car tourists, homeward trip, mobile probe data**

I. Introduction

Traffic congestions frequently occur on expressways connecting to metropolitan areas in Japan during weekends and holidays, due to the concentration of return traffic from surrounding tourism areas to metropolitan areas, resulting in a huge loss of time for car travelers. A study by Kawahara (2003) shows that congestion can be mitigated by postponing the departure time of some of the vehicles involved in the congestion [1]. In the meantime, a survey conducted in tourism spots in Yamanashi prefecture of Japan reveals the possibility of postponing home return time, as over 60% of the surveyors expressed that they would like to change their home return time depending on the congestion condition [2]. On the other hand, in recent years, with the spread of smartphones, real-time traffic information is easily obtained, and along with the increase in people's information sensitivity, behavioral change tends to be induced by real-time information.

The authors have proposed to develop a mobile application that provides predicted near future traffic congestion and surrounding tourism information at the same time, for the purpose of inducing additional stopovers in tourism areas on the way home to avoid becoming involved in traffic congestions, which is beneficial to both tourism promotion and traffic congestion mitigation.

As a first step, it is necessary to understand the actual situation of additional stopovers on the way home, and grasp the overall tendency of car tourists' stopover behaviors. However, it has not been clarified so far whether car tourists actually take additional stopovers for the purpose of congestion avoidance, and if so, under what conditions car tourists are more likely to make more additional stopovers.

Therefore, this research made an attempt to use the actual route search data and GPS travel trajectory data collected by mobile car navigation system to identify the tendency of car tourists' additional stopover behaviors.

Many researches can be found on travel and tourist behavior analysis using GPS trajectory data in transportation and tourism fields [3]-[5]. For instance, Araki (2018) analyzed the impacts of seasonal factors on travel behavior using GPS trajectory data for eight months [6]. Calabrese (2013) presented techniques to extract useful mobility information from the mobile phone traces to investigate individual mobility patterns [7]. Similarly, movement patterns of tourists based on GPS data are also explored [8]-[10]. Some researchers also combined GPS

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data with other data for analysis. For example, East (2017) proved that combining GPS trajectory data and survey data can improve understanding of visitor behavior [11]. On the other hand, there are very few research on stopping behavior of car tourists in the tourism field [12]. Newton (2017) investigated the spatial temporal patterns of vehicle stopping behavior along park roads [13]. However, there is a surprising neglect of the research focusing on the congestion avoidance behavior of home return traffic for tourism purpose. In addition, no research can be found so far that analyzes the actual situation regarding additional stopover behavior and activities with the relations with traffic congestion. The reason might be it is hard to identify whether the stopovers are "planned" or "additional". By combining the route search data with actual travel trajectory data, this study is able to identify additional stopovers through perceiving car tourists' intention to return home from the action of conducting a "home return route search".

II. Study Methods

This empirical study focuses on the additional stopover behaviors of car tourists in the home return traffic from tourism area to metropolitan area, attempting to clarify the tendency of additional stopovers in different departure time periods for homeward trip under several levels of traffic congestion conditions. The study mainly uses two types of data, namely "route search data" and "mobile GPS travel trajectory data (probe data)" to identify the additional stopovers; in the meantime, traffic congestions data is also used to estimate the levels of traffic congestion condition expressed as congestion length at the time when the vehicle reaches the congestion point.

A. *Identifying Additional Stopovers*

In this study, "additional stopover" is defined as "the temporary interruption of travel trajectory after the car tourist started the navigation for homeward trip." Specifically, to be regarded as "additional stopover", the following three conditions need to be met.

a. Car tourist is traveling on the homeward route
b. Travel trajectory is temporarily interrupted
c. A certain staying time occurs after the interruption

Fig. 1 shows the process of the identifying additional stopovers.

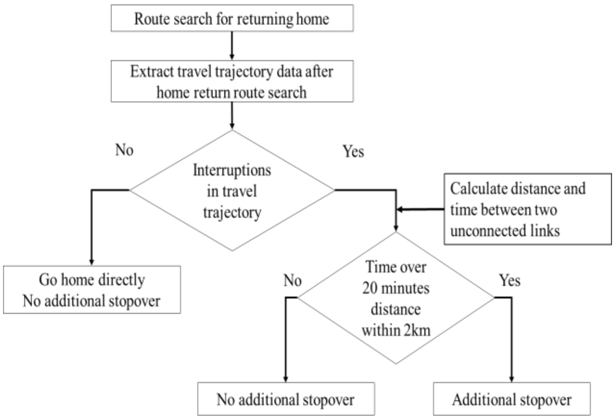

Figure 1. Flowchart of identifying additional stopovers

First, in order to determine "a. Car tourist is traveling on the homeward route", "route search data" collected by mobile car navigation system is used. The time point at which the car tourist executed a route search with the destination set as "home" and started navigation of the homeward route is defined as "departure time for homeward trip". The stopovers occurring after "departure time for homeward trip" are considered to meet condition a. Additionally, in order to make sure the route search for homeward trip originates in the tourism areas and is headed to the metropolitan area, the route search data is limited to the route searches where the origin location is a tourism area ("Yamanashi prefecture" and "Nagao prefecture", two popular tourism areas near by Tokyo Metropolitan area, are used as the keywords of origin location for route search in this study), and destination location is a metropolitan area ("Tokyo", "Saitama prefecture", "Ibaraki prefecture", "Chiba prefecture", and "Kanagawa prefecture" in Tokyo metropolitan area are used as the keywords of destination for route search in this study).

Next, conditions "b. Travel trajectory is temporarily interrupted" and "c. A certain staying time occurs after the interruption" are applied to examine the travel trajectory data collected between the departure time for homeward trip to the time point that the vehicle enters the expressway. As the purpose of the study focuses on the additional stopovers in the tourism areas, we assumed that no additional stopovers occur after the vehicle enters the expressway, which helps to narrow the data processing amount and eliminate the stopovers out of purpose. "Route search data" and "Mobile GPS travel trajectory data" are linked with a common matching user ID, so the travel trajectory after route search for homeward trip can be obtained as study targets for examining interruptions in travel trajectory. Specifically, the method to identify "interruption" is to check the connectivity of trajectory links and extract the links which are not connected with the previous link. However, besides stopovers for tourism purposes, navigation interruptions also occur for different reasons such as re-search of the route. Therefore, it is necessary to discriminate stopovers with navigation interruptions due to other reasons. Therefore, time and position information of the two unconnected links are acquired, and road distance between the two unconnected links are calculated by Google API based on the location coordinate of the unconnected links. The criteria to determine "stopover" is "interruptions that the time difference of the two unconnected links is over 20 minutes and the distance between the location of the two unconnected links is within 2 km. The interruptions failed to meet the criteria are excluded from target data.

B. *Estimating Traffic Congestion Length*

When executing route search using mobile car navigation system, users generally get access to the traffic information including optimal route and time required to arrive to the destination. Real-time traffic congestion is reflected in the time required to arrive destination. This information may influence car tourists' travel behavior on making additional stopovers to avoid becoming involved in a traffic congestion. In this study, the estimated traffic congestion length is used to reflect travel congestion information received by users, as congestion length is closely correlated with the time involved in congestion that greatly affects the require time to arrive destination. As shown in Fig. 2, Congestion length is defined as the distance between the points where congestion starts with where congestion ends. The longer the congestion length is, the greater time it requires to reach destination.

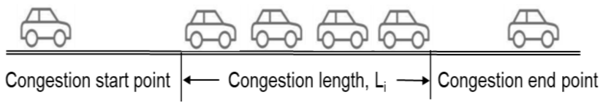

Figure 2. Image of congestion length

According NAVITIME JAPAN Co., Ltd., who provided route search and mobile GPS trajectory data for this study, the required time to the destination is calculated based on the congestion at the time point when the vehicle reaches congestion point. Therefore, in this study, congestion length is also estimated at the time point when the vehicle reaches the congestion start point, using congestion data which includes congestion start time, congestion end time, and maximum congestion length at respective study days. The time point when the vehicle reaches the congestion point is obtained by Google API for required time calculation with the origin as the location of departure for returning home and the destination as the location of the congestion point. Generally, the congestion length increases monotonously toward the congestion peak time and decreases monotonously after congestion peak time. In this study, the congestion length is assumed as a linear function before and after the congestion peak time. The formula is as follows:

$$L_i = \begin{cases} \dfrac{L_{max}}{(t_{max} - t_{start})} \times \ (t_{max} - t_i) \quad (if\ t_i < t_{max}) \\ \dfrac{L_{max}}{(t_{max} - t_{start})} \times \ (t_{end} - t_i) \quad (if\ t_i \geq t_{max}) \\ 0 \qquad (if\ t_i \leq t_{start}, t_i \geq t_{end}) \end{cases}$$

where

L_i: The estimated congestion length when the vehicle arrives at the congestion point

L_{max}: The maximum congestion length of the study dates

t_i: The estimated time when the vehicle arrives the congestion point

t_{max}, t_{start}, t_{end}: the time points when congestion reaches the maximum length, congestion starts, and congestion ends on the study dates, respectively

III. Study Area

The study target is the traffic passing through the Kobotoke tunnel of the Chuo Expressway, which is a famous traffic congestion bottleneck in the Tokyo metropolitan area. According to the "Worst ranking of traffic congestion" published by Ministry of Land, Infrastructure, Transport and Tourism (MLIT) of Japan in 2018, congestions resulted by the traffic concertation at the Kobetoke tunnel ranked 10th throughout the whole year, but ranked 2nd during the tourism seasons such as the Golden Week (A week long holiday in Japan during late April to early May) - reflecting a typical tourism induced congestion bottleneck [14]. In addition, Chuo Expressway connects to Yamanashi prefecture and Nagao prefecture, which are abundant with tourism resources such as "Kofu Basin", "Yatsugatake Tourism Area", and "Fujisan and Fuji Five Lakes Tourism Area". Therefore, it is an area that is appropriate for studying additional stopovers for tourism purpose induced by traffic congestions.

IV. Study Data and Data Preparation

A. Data Overview

The following three types of data are used in this study.

1) Route search data

Route reach data are acquired when users conduct a route search. In this study, route search data are obtained from mobile car navigation services "NAVITIME Drive Supporter" and "Car Navitime" operated by NAVITIME JAPAN Co., Ltd.. Table I shows the details of the information contained in "Route search data". The gravity of the third mesh is used as the coordinates of the origin and the destination, as the coordinate of the origin and the destination is deleted for privacy protection purpose. Total data amount is 59,543 record counts, and 11,450 persons.

TABLE I. Details of Route Search Data

Item	Description
Matching ID	A common user ID that links route search data with travel trajectory data
Request time	Route search execute time
Specified time	Specified departure time
Origin coordinate	Delete for privacy protection
Origin 3rd mesh	1km×1km grid according to Japanese standard
Destination coordinate	Delete for privacy protection
Destination 3rd mesh	1km×1km grid according to Japanese standard

2) Mobile GPS travel trajectory data (Mobile probe data)

Mobile GPS travel trajectory data are acquired when users start car navigation using mobile car navigation application. The mobile GPS travel trajectory data used in this study is also obtained by the same mobile navigation applications of "route search data". The latitude and longitude information are recorded at intervals of one to six seconds by GPS. Data within 100 m of origin and destination are deleted for privacy protection purpose. Table II shows the details of the information contained in "Mobile GPS travel trajectory data". Total data amount is 12,243,793 record counts, and 11,450 persons.

3) Congestion data

Congestion data used in this study are the information of the congestions that occurred in the sections between Hachioji and Ostsuki entrance/exits on the Chuo Expressway, which were provided by Central Nippon

Expressway Company. The congestion data includes the information of congestion start time, congestion end time, maximum congestion length and congestion causes for Sunday and the last day of long holiday during the period of July 2017 to July 2018.

TABLE II. DETAILS OF TRAVEL TRAJECTORY DATA

Item	Description
Matching ID	A common user ID that links route search data with travel trajectory data
Link length	Length of the link
Approaching time	Time when the vehicle enters the link
Leaving time	Time when the vechile leaves the link
Link connectivity	if the link is connected with previous link
Geom	Geolocation information of the link

B. Data Preparation

Here are the steps for extracting the data that used for analysis in this study.

1) Narrow down study days

From the traffic congestion data of a one-year period, among traffic congestions caused by traffic concentration, 30 days in which typical traffic congestion occurred where the maximum traffic congestion length and traffic congestion time are correlated are selected and used as the target study days. In order to examine the tendency of additional stopovers under various congestion conditions, the days with different levels of congestions are selected as study target.

2) Extract route search data for returning home

Using the method described in II study method, 4,214 route search data for returning home by matching ID was extracted and used for extracting travel trajectory data.

3) Extract travel trajectory data

Travel trajectory data between the departure time for homeward trip and the time entering the expressway were extracted by the common matching ID obtained from route search data. Travel trajectory data with less than a five-minute time gap between the departure and expressway entry times are excluded as additional stopovers are not possible within five minutes. Travel trajectory of 3, 323 matching ID are finally used for identifying additional stopovers.

4) Identify additional stopovers

Using the method described in II study method, 413 record counts and 359 persons of additional stopovers were successfully extracted, of which 54 persons made two stopovers.

V. STUDY RESULTS AND DISCUSSION

A. Additional Stopovers Ratio by Time Periods

Fig. 3 shows the tendency of the additional stopovers by one-hour time period. Additional stopover ratio is defined as the ratio of the number of car tourists that made additional stopovers, to the total number of car tourists that conducted route search for homeward trip in a one-hour time period of departure time. From Fig. 3, it can be seen that the earlier the departure time is, the higher the additional stopover ratio is. This result seems to be intuitively understandable as there is more time allowance for making additional stopovers when car tourists depart early in the day. This trend is particularly obvious at the 12:00-14:00 time period that has very high additional stopover ratio. However, the additional stopover ratio significantly drops when the departure time for returning home is later than 20:00.

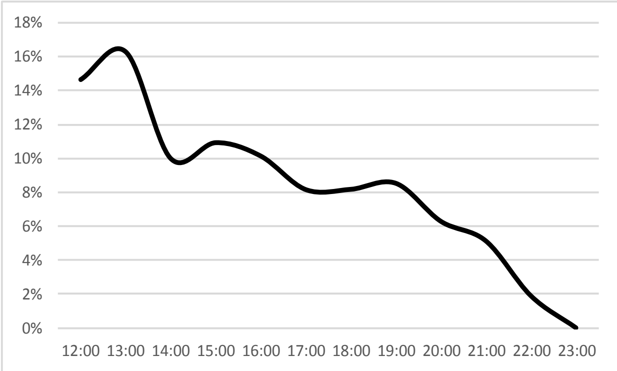

Figure 3. Ratio of additional stopovers by the times period of departing for returning home

The departure times for returning home are grouped into 4 time periods: 12:00-14:00, 14:00-17:00, 17:00-20:00 and after 20:00. The distance from the departure location to destination (home) is calculated, and the average distances in 4 groups are 143 km, 144 km, 144 km, and 142 km respectively. No significant differences in the distances between departure location and destination can be confirmed in the results of variance analysis either ($p=0.978$). Normally, car tourists tend to return home early if their home is far; however, as the study target is limited to home return traffic from Yamanashi and Nagano prefecture to the Tokyo metropolitan area, significate difference in home distance cannot be found among the 4 time periods groups.

B. Additional Stopover Ratio by Time Period and Estimated Congestion Length

Applying the study method described in section II part B. Estimating traffic congestion length, the congestion length when the car tourist conducted route search for homeward trip is estimated. Additional stopover ratio by time period under the situations of no congestions and different congestion levels are shown below.

1) Additional stopover ratio of no congestion and under congestion by time period

If estimated congestion length is 0, it means no traffic congestion happens on the route for returning home; otherwise, some extend of traffic congestion occurs. Fig. 4 shows additional stopover ratio of no congestion and under congestion in the 4 groups of departure time period respectively. It is obvious that in all time period groups, additional stopover ratio of no congestion is lower than that of under congestion. This result implies that car tourists tend to take more additional stopover overs when traffic congestion is observed on the homeward route.

2) Additional stopover Ratio by time period under different congestion levels

Furthermore, the estimated congestion lengths are grouped into 4 groups representing the different level of congestions: 0-5km, 6-15 km, 16-25 km, over 25 km. The additional stopover rate by time periods and congestion lengths is shown in Table III.

Looking at the tendency of the additional stopover ratio in each time period, it seems that additional stopover ratio increases as the congestion length increases. However, for the time periods after 17:00, when congestion length exceeds 25 km, the additional stopover ratio drops. In other words, it is considered that the longer the congestion length is, the stopover ratio is likely to increase; however, when looking into different time periods, the congestion length and the stopover ratio may not be correlated linearly.

In the case of the early departure time, when the congestion length gets long, it is interpretable that car tourists tend to make additional stopovers to avoid congestions as there are plenty of time left for homeward trip. On the other hand, in the case of late departure time, from the traveler's psychology, when the congestion length is not so long, the traveler tends to make additional stopover to avoid congestion; however, when the congestion length gets very long, the traveler may refrain from additional stopover as the home arrival time will get very late.

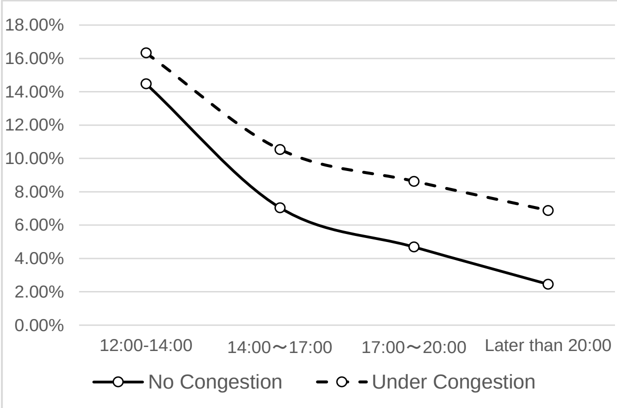

Figure 4. Additional Stopover Ratio of no congestion and under congestion by time period

TABLE III. THE ADDITIONAL STOPOVER RATIO BY DEPARTURE TIME AND CONGESTION LENGTHS

		0–5km	6–15km	16–25km	over 25km	Total
12:00–14:00 (n=951)	No. of home return car tourists (a)	664	217	65	5	951
	No. of car tourists made additional stopovers (b)	96	36	12	3	147
	Additional stopover ratio (b/a)	14.50%	16.60%	18.50%	60.00%	15.50%
14:00～17:00 (n=1342)	No. of home return car tourists (a)	219	592	426	105	1342
	No. of car tourists made additional stopovers (b)	22	43	50	22	137
	Additional stopover ratio (b/a)	10.00%	7.30%	11.70%	21.00%	10.20%
17:00～20:00 (n=678)	No. of home return car tourists (a)	113	197	221	147	678
	No. of car tourists made additional stopovers (b)	6	18	25	7	56
	Additional stopover ratio (b/a)	5.30%	9.10%	11.30%	4.80%	8.30%
Later than 20:00 (n=352)	No. of home return car tourists (a)	212	82	53	5	352
	No. of car tourists made additional stopovers (b)	6	7	4	0	17
	Additional stopover ratio (b/a)	2.80%	8.50%	7.50%	0.00%	4.80%

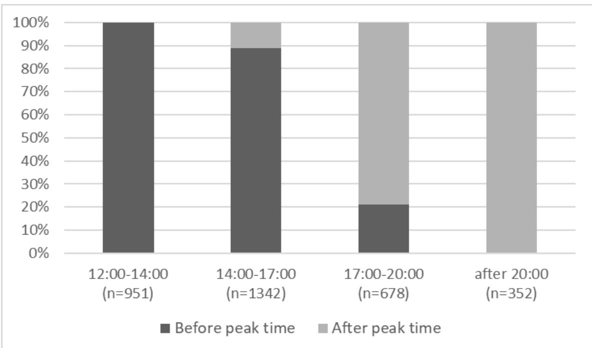

Figure 5. Composition ratio of the car tourists arriving before and after the peak hour by departure time

However, going home directly without making additional stopovers when congestion is heavy seems not be a reasonable choice. As shown in Fig. 5, regarding the composition ratio of travelers arriving before or after the congestion peak, almost 80% of the travelers that departed after 17:00 to head home arrived at the congestion point after the congestion peak, which means that if they make additional stopovers to postpone the arrival time at the congestion points, the congestion length will be shorter than the estimated congestion lengths. From the viewpoint of congestion avoidance, it is better for them to make additional stopovers. If traffic conditions can be accurately recognized, travelers may be able to make effective additional stopovers to avoid congestion. This implies the possibility of inducing additional stopovers by providing near future congestion information.

VI. CONCLUSION AND FUTURE STUDY

The study examines the actual situation of additional stopovers made during the homeward trip. By using linked data of route search for homeward trip with travel trajectory after the route search, the study successfully identified the additional stopovers during the homeward trip. The study results show the tendency of additional stopover behaviors in different departure time periods and under various congestion conditions.

However, for this study, though influence of traffic congestion on additional stopover behaviors can be observed to some extent, it is hard to conclude that the observed stopovers are induced by traffic congestion. In the future study, factors such as attractiveness of sightseeing spots, business hours of facilities and restaurants, individual attributes are planned be added as variables to statistically examine the stopover behaviors and quantitatively figure out the impact of traffic congestion on additional stopover behaviors. Furthermore, a mobile application that provides predicted near future traffic congestions and surrounding tourism information is planned to be developed and used for a social experiment, to practically verify the effect of congestion mitigation and tourism promotion through prompting proper additional stopovers at the tourism area. The study results will contribute to support tourism promotion policies such as extending business hours of tourism facilities, or planning time-limited activities during home return peak hours, which is beneficial to both tourism promotion and traffic congestion relief.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Y. L. and S. A. conducted the research; Y. L. analyzed the data and wrote the paper; S. A. and K.T performed data curation; all authors had approved the final version.

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