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Examining difference between paper- and web-based self-reported departure/arrival time using smartphone-based survey

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Abstract

In this study, we compare paper- and web-based self-reporting survey results with smartphone-based survey data. The focus is on the error in the departure or arrival times of the trips reported by the participants and it is measured by the time difference between smartphone-based and self-reporting survey results. Most of the results show that the time difference for the web-based survey is larger than that for the paper-based survey. We find that the burden of the paper-based survey may increase the time difference. The number of elapsed days taken to record impacts the time difference, particularly in the web-based survey. Furthermore, for a young long-time internet user, the paper-based survey results are less accurate.

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Keywords: paper-based survey; web-based survey; smartphone-based survey; time difference; rounding error; reporting error

1. Introduction

Mail-based and door-to-door survey methods (paper-based survey) have been often adopted for household travel surveys or other travel surveys. However, some researchers are concerned about its cost-effectiveness because these classical methods require expensive surveys and are highly burdensome for the participants. Consequently, recently, web-based surveys were implemented as an alternative to the paper-based survey method. Furthermore, a smartphone-based method was proposed as a new method (e.g,. Thomas et al. 2018, Gadzinski 2018, Allstrom et al. 2017, Danalet and Mathys 2017, Safi et al. 2017, Zhao et al. 2015, Montini et al. 2015, Geurs et al. 2015, Berger and Platzer 2015, Greaves et al. 2015, Qudratullah and Maruyama 2019a, 2019b, 2019c, Qudratullah et al. 2019). The 2012 Kumamoto person trip (PT) survey (or household travel survey) that was conducted in Japan was the first smartphone-based survey

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performed in combination with paper- and web-based surveys. Using these survey results, Maruyama et al. (2014) and Maruyama (2015) compared smartphone-, paper-, and web-based survey findings.

However, their analysis had some limitations because the participants in the 2012 Kumamoto survey had to choose between a paper- and web-based method, and the comparison made by the authors was based on different participants. To overcome their limitation, this study conducts survey with three methods, paper-, web- and smartphone-based in the same time and same participants. The focus is on the error in the departure or arrival times of the trips reported by the participants. We measure the error by the time difference between smartphone-based and self-reporting survey results because smartphone-based survey enables recording their travel behavior more accurately using the GPS. These errors can be different between paper- and web-based methods, and it will be affected by gender and other characteristics of participants. The error can be increased if the participants forget the survey record and they must remember the trip diaries long day before. In other words, the error can be a function of the number of elapsed days to record. These issues are not fully investigated in the previous studies. Then, the objective of this study is as follows:

(1) To reveal the error in the self-reported departure or arrival times of the trips in the same participants by comparing paper-, web-based, and smartphone-based survey data.
(2) To investigate the effect of participants characteristics on the error.
(3) To examine the effect of elapsed days to record affected the time difference,

Many existing study stated the presence of some kinds of errors in the response data of paper- and web-based survey methods because the participants usually answer these surveys based on their own memories (e.g,. Stopher et al. 2007, Department for Transport 2012, Shen and Stopher 2014, Zhao et al. 2015). Some researchers focused on the effect of rounding errors of departure/arrival time (e.g. Levinson 1995, Murakami and Wagner 1999, Rietveld 2001), difference of travel time (e.g,. Kelly et al. 2013, Varotto et al. 2017), travel distance (e.g,. Witlox 2007, Blanchard et al. 2009) or trip rate (Bricka and Bhat, 2006). However, few studies focused on the difference between paper- and web-based survey. Then, the novelty of this study is to investigate the difference between paper- and web-based survey results using smartphone-based survey as innovative travel survey method.

2. Method

2.1. Smartphone-based survey system

Maruyama et al. (2014, 2015) developed a smartphone-based travel survey system. First, the participants register on the official website, and input their personal information. After registration, they receive their own identification (ID) and password. Then, they obtain the survey application from the application (app) store. They download and install the application on their own devices. The application requires authorization for the first time to start. Finally, the participants start participating in the survey by tapping the "Start" icon in the application, and the GPS location data, time, and three-dimensional acceleration data (Android version only) are sent to our secure data server by 3G/4G or a Wi-Fi network.

2.2. Overview of Survey

In this study, the participants participate in three survey methods (paper-, web-, and smartphone-based). We recruit 30 participants. All the participants reside in the Kumamoto metropolitan area, Japan. Fifteen participants are students of Kumamoto University, and the other 15 participants are from the general public. We divide all of participants into two groups. Table 1 summarizes the details of this survey design in each group. We conduct the survey using the same format as the Kumamoto PT survey for the paper- and web-based surveys (Figs. 2 and 3 and Table 3).

The details of the survey are as follows:

- Survey period: From January 19 to 23, 2015.
- Participants: 15 students from Kumamoto University, and 15 from the general public
- Sample collection method: Snowball sampling

Table 1. Summary of the survey design

Group 1	Day 1	Day 2	Day 3	Day 4	Day 5
Paper-based	Yes	Yes			
Web-based			Yes	Yes	Yes
Smartphone-based	Yes	Yes	Yes	Yes	Yes

Group 2	Day 1	Day 2	Day 3	Day 4	Day 5
Paper-based			Yes	Yes	Yes
Web-based	Yes	Yes			
Smartphone-based	Yes	Yes	Yes	Yes	Yes

The participants start the smartphone-based survey application before starting the first trip and continue to run it until the arrival of the last trip of the day. If the participants go to hospitals or theaters, they turn-off their own devices (apps), but after the participants depart from these facilities, they start the application again. After completing the smartphone-based survey, the participants report the paper- or web-based surveys. We told them to answer these surveys using the same attitude as a typical governmental survey. In addition, we asked the participants to record the date they answered the survey. We aimed to analyze how these factors affect the result.

3. Results

3.1. Demographic distribution of participants

We divided the participants into two groups of equal numbers. Figure 1 displays the gender distribution. The student group has more male participants than female participants. The general group has more female participants than male participants. We set two groups such that they do not have a bias in gender distribution. Figure 2 shows the age distribution. The number of 35–39 old male participants is more than that of other ages. In comparison, various generations of female participants participated in this survey in the general group.

Table 2. Group setting of the survey.

Group of the Survey	Attribution Group	
	Student	General
Group 1 (2 days of paper-based survey, 3 days of web-based survey)	7	7
Group 2 (3 days of paper-based survey, 2 days of web-based survey)	8	8

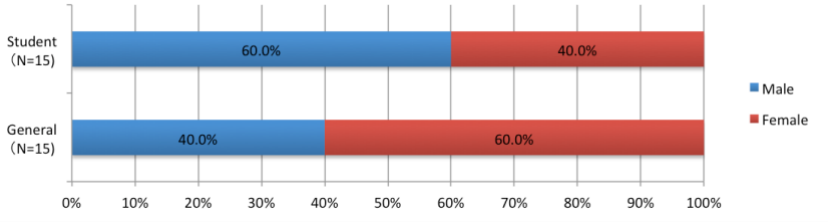


Fig. 1. Gender distribution of the participants

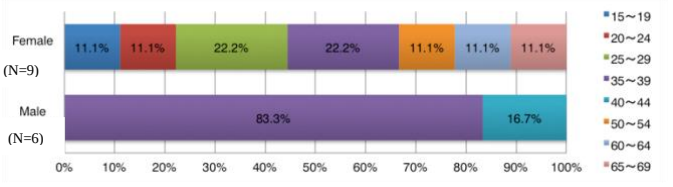


Fig. 2. Age distribution of the participants in the general group

3.2. Difference of departure/arrival time between survey methods

We defined "time difference" as the difference in the departure or arrival time of the paper- or web-based survey and smartphone-based survey. Specifically, we estimated the time difference by the following procedure:

- First, we investigate each departure/arrival time of a trip in the paper- or web-based survey.
- We search the same trip in the GPS tracking data and departure or arrival time is determined
- We calculate the time difference from eqns. (1) and (2).

$$t_s = \text{(Departure time of Paper -based or web-based survey)} - \text{(Departure time of Smartphone-based survey)} \quad (1)$$

$$t_e = \text{(Arrival time of Paper -based or web-based survey)} - \text{(Arrival time of Smartphone-based survey)} \quad (2)$$

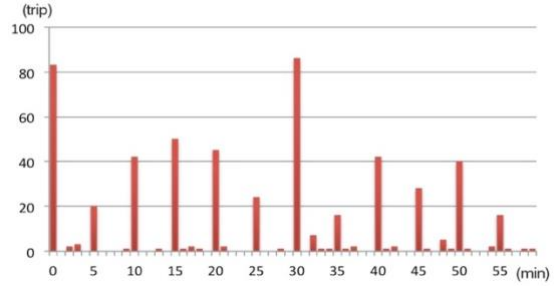


Fig. 3(a). Distribution of the departure time (paper-based and web-based)

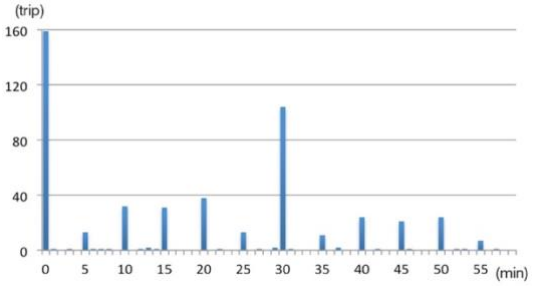


Fig. 3(b). Distribution of the arrival time (paper-based and web-based)

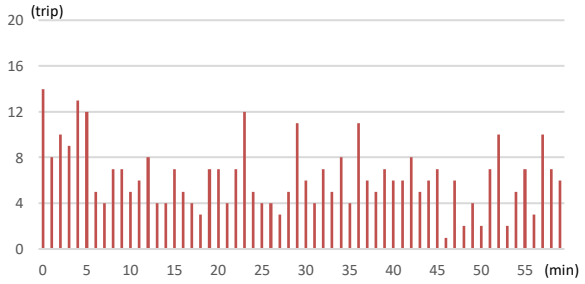


Fig. 3(c). Distribution of the departure time (smartphone-based)

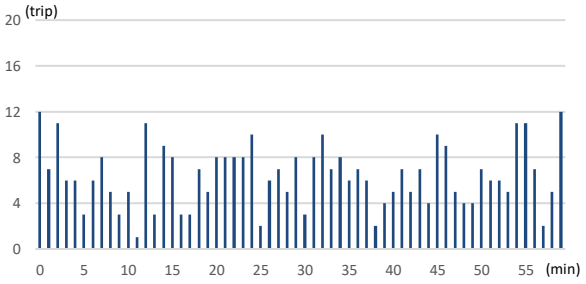
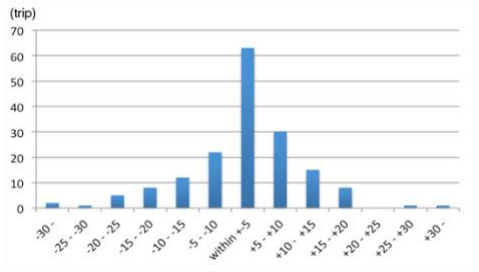


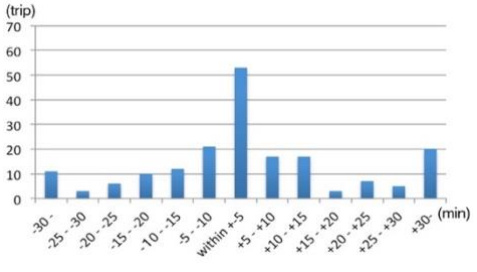
Fig. 3(d). Distribution of the arrival time (smartphone-based)

Figure 3 summarizes the distributions of the departure/arrival time of a trip in each survey. Comparing between smartphone-based survey (Fig.3(c,d)) and other surveys (Fig.3(a,b)), participants tend to report the departure time in a 5-min step in paper- or web-based survey, that is called as "Rounding errors" (e.g,. Levinson 1995, Murakami and Wagner 1999, Rietveld 2001). In addition, various participants reported in 0- or 30-min steps, and this has a stronger correlation with the departure time than the arrival time.

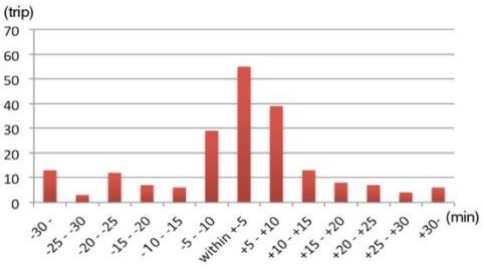
Based on the results in Figure 3, we present in Figure 4 a histogram of the time difference distribution in steps of 5 min. The time difference for the paper-based survey tends to be less than that for the web-based survey. In addition, the number of times the time difference exceeds 30 min is larger for the web-based survey than for the paper-based survey. It seems that the participants might answer incorrectly in the web-based survey because the input form of the departure or arrival time was "select box" style in this survey.



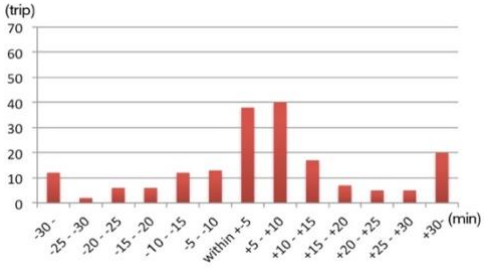
(a) Paper-based departure time difference



(b) Web-based departure time difference



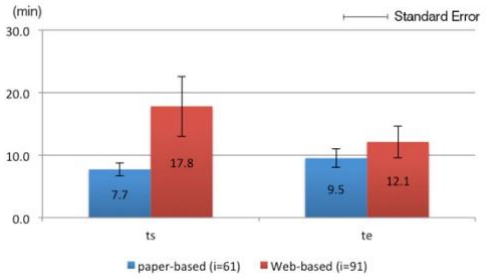
(c) Paper-based arrival time difference



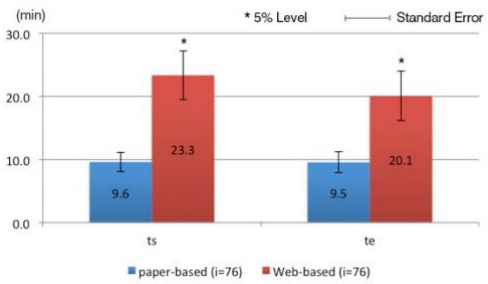
(d) Web-based arrival time difference

Fig. 4. Distribution of the time difference in the smartphone-based and self-reporting surveys

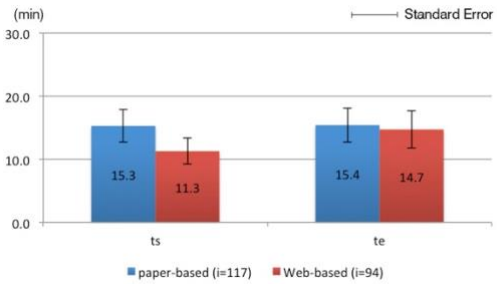
3.3. Comparison of time difference: Gender



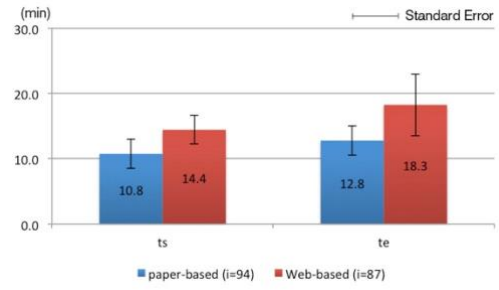
(a) Male with $t_s > 0$ or $t_e > 0$



(b) Female with $t_s > 0$ or $t_e > 0$



(c) Male with $t_s < 0$ or $t_e < 0$



(d) Female with $t_s < 0$ or $t_e < 0$

Fig. 5. Time difference for the smartphone-based and self-reporting surveys as a function of the gender (*i*: number of trips)

Figure 5 summarizes the time difference as a function of the gender. Most of the results show that the time difference for the web-based survey is larger than that for the paper-based survey, and interestingly, the time difference for the paper-based survey in the Figure 5(c) is slightly more than that for the web-based survey. In addition, it is significantly different for the two survey methods in the Figure 5(b) (both for departure and arrival) based on the t test at 5% level.

In the next section, we use the absolute value of the time difference as defined below.

$$T_S = |t_s| \tag{3}$$

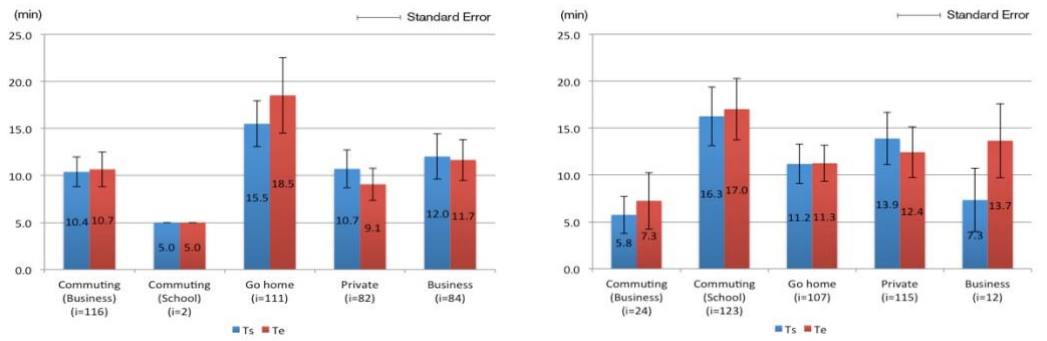
$$T_e = |t_e| \tag{4}$$

T_s: Time difference of departure (absolute value) T_e: time difference of arrival (absolute value)

3.4. Comparison of time difference: trip purpose

Figure 6 presents the time difference for both the groups as a function of each purpose. The time difference for a commuting (business) trip in the general group is less than that for other purposes, and the time difference for commuting to a school in the student group is more than for other purposes. The reason could be that university students did not commute to school regularly because there was no lecture in the survey period, and most of Bachelor 4th grade and Master 2nd grade students were writing their graduation thesis in Japan.

In the general group, there is an apparent difference in the going-home-trip for the survey methods, but it is not a significant difference based on the t test at 5% level. In addition, we compared the similarity in the time difference in the departure and arrival zones because it seems that most of the students may live around the university in this case. However, this also does not have a significant difference.



(a) general group (b) student group

Fig. 6. Time difference for the smartphone-based and self-reporting surveys in terms of the trip purpose (*i*: number of trips)

3.5. Comparison of each survey: elapsed days to record

We asked the participants to answer the elapsed days to record the behavior. Figure 7 shows the distribution of the elapsed days for both the survey methods. We defined elapsed days as the duration between the reporting day and survey day. In the paper-based survey, numerous participants answer in less than two days, whereas, in the web-based survey, the elapsed days are three or four days more than that for the paper-based survey. This suggests that the participants have more time to answer in the web-based survey than that in the paper-based survey.

Some participants answered at one time because this survey continued over five days. We divided the participants into two groups: participants who answered at one time and did not-answer at one time.

Figure 8 displays the distribution of the time difference for each group. For the did not-answer at one time group, elapsed days of more than four days are not collected. In this survey, the duration between the last-survey-day and

deadline of submitting the survey data is a week. Therefore, the participants tend to answer at one time in case the duration is over four days. In addition, in the answered at one time group, the time difference for the paper-based survey tends to increase beyond 6 days. In contrast, in the did not answer in one time group, the time difference tends to increase gradually beyond 2 days.

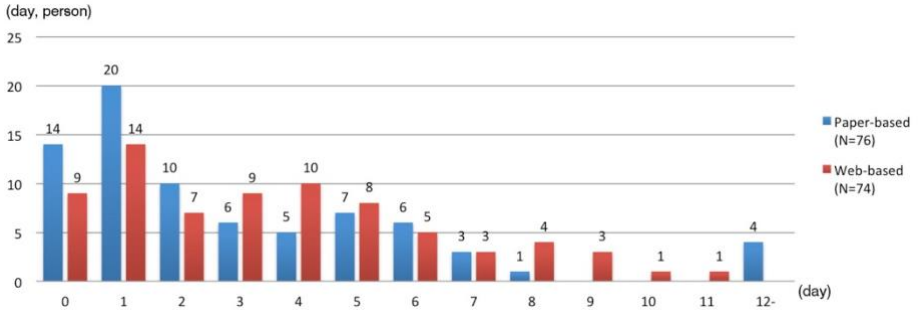
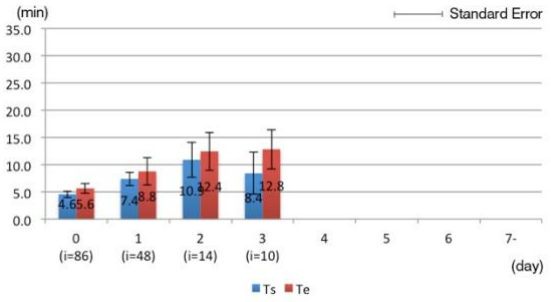
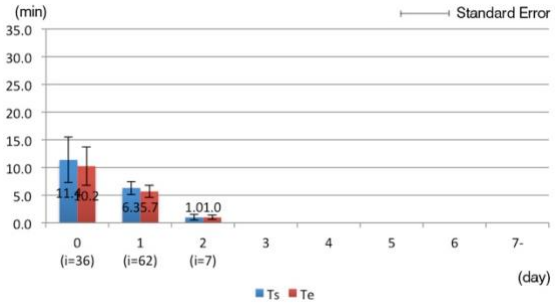


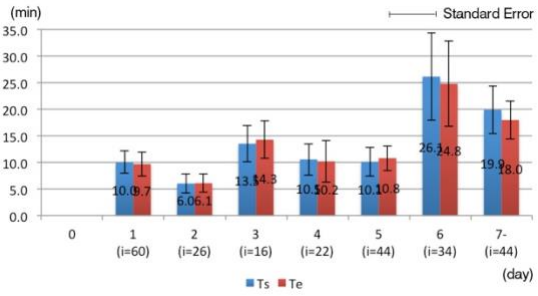
Fig. 7. Distribution of the elapsed days to record for both the survey methods



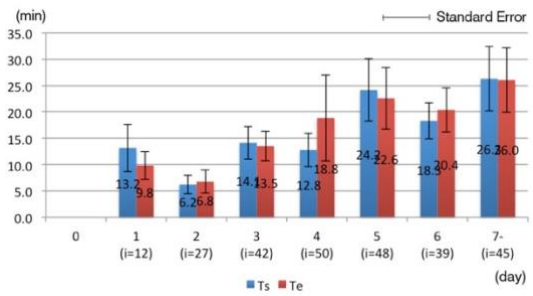
(a) paper-based and did not answer at one time



(b) web-based and did not answer at one time



(c) paper-based and answered at one time



(d) web-based and answered at one time

Fig. 8. Time difference between smartphone-based and self-reporting survey in terms of the answering style

3.6. Comparison of each survey: sense of survey burden

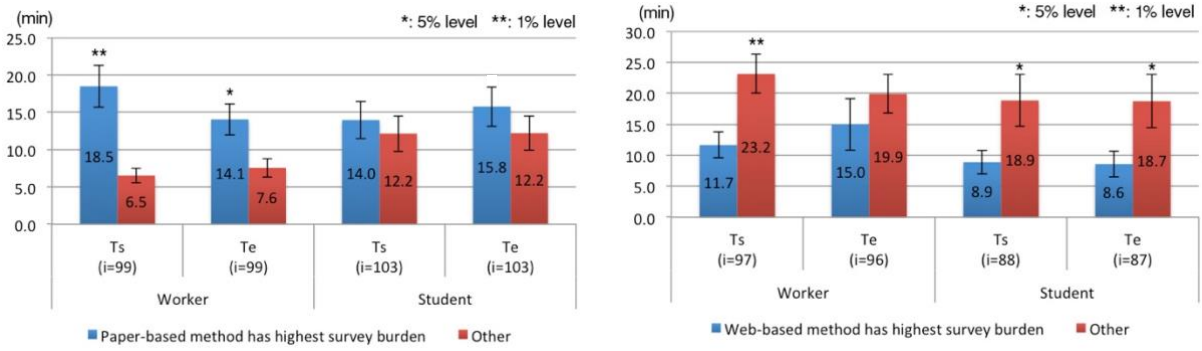
We collected the sense of the survey burden of the participants for each survey method. In this section, we analyze how the burden level affects the result of each survey. The participants ranked the sense of the survey burden of the paper-, web-, and smartphone-based surveys after finishing the surveys. We divided the participants into two groups using the answers whether they felt burdened in each survey, and we analyzed the difference between each group.

Figure 9 summarizes the time difference of each group. In the paper-based survey, the time difference of group which thinks the paper-based method has the highest survey burden is higher than or the other group. In the general group, the departure and arrival times have a significant difference by the t test at 1% level. In the student group, the arrival time has a significant difference by the t test at 5% level.

In contrast, in the web-based survey, the time difference of group which thinks the web-based method has the highest survey burden is lower than of the other group. In the general group, the departure time has a significant difference by the t test at 1% level. In the student group, the departure and arrival times have a significant difference by the t test at 5% level.

It seems that there is a significant time difference for the participants who think the paper-based method has the highest survey burden because recently they would have had fewer opportunities for writing on paper. Concurrently, Figure 9 indicates that the participants who did not have most survey burden would answer in the departure or arrival time, which is the most complex part in this survey, without much consideration because they would like to finish answering as soon as possible.

In addition, it seems that there is not much difference in the student group in the paper-based survey because the students have more opportunities for writing something at their schools.



(a) paper-based (b) web-based

Fig. 9. Time difference between smartphone-based and self-reporting survey by level of survey burden

3.7. Comparison of each survey: internet use time

We divided the participants into two groups by their internet use time. We defined the participant who uses internet longer than the average of the same generation (Table. 2) as ‘long-time internet user’ and defined the participant who uses internet shorter than the average of the same generation as ‘short-time internet user’. Using this definition, 6 out of 15 student participants are classified as short-time user, and the other 9 participants are long-time user. Coincidentally, 6 out of 15 general participants are classified as short-time user, and the other 9 participants are long-time user.

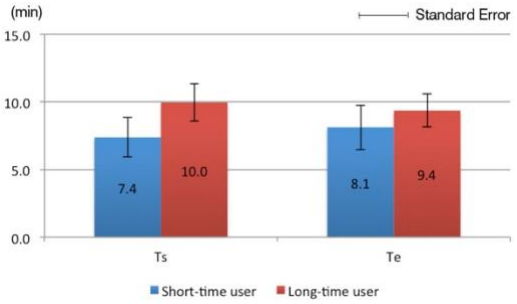
Figure 10 shows the comparison of the time difference based on the groups and survey methods. In the student group, there is a significant difference in the time difference between the long-time internet user group and short-time internet user group by the t test at 5% level. There is also a similar tendency in the web-based survey, but there is no significant difference.

In addition, Figure 11 illustrates the distribution of the level of the survey burden for each group. We summarize by the rank of the paper-based survey in Figure 11(a), and summarize by the rank of the web-based survey in Figure 11 (b). In the paper-based survey, the distribution of the participants who think the paper-based method has the highest survey burden is higher in the long-time internet user group than in the short-time internet user group, and there is significant difference at 5% level. Concurrently, in the web-based survey, the distribution of the participants who do not consider the web-based method has highest survey burden is higher in the short-time internet user group than in the long-time internet user group at 1% level.

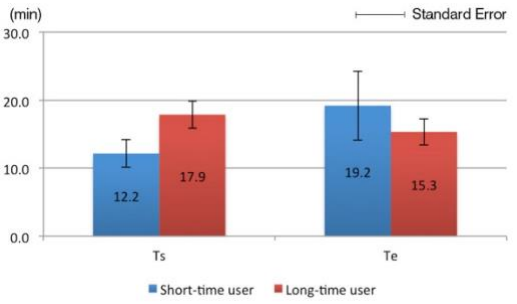
Table. 2 Daily internet use time in weekdays in Japan

Age	*N*	Average time (min)
10s	278	99.1
20s	446	136.7
30s	572	87.8
40s	592	70.0
50s	512	61.8
60s	600	36.7
Total	3,000	77.9

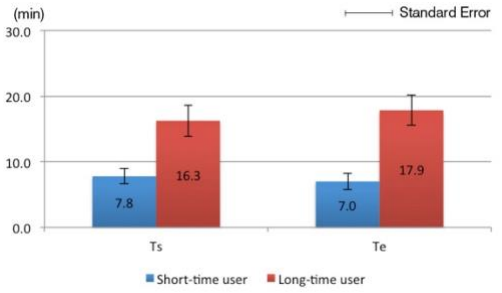
Source) Institute for Information and Communication Policy (2013)



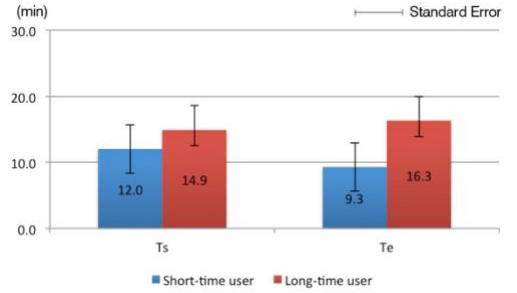
(a) Paper-based record general group



(b) web-based record by general group

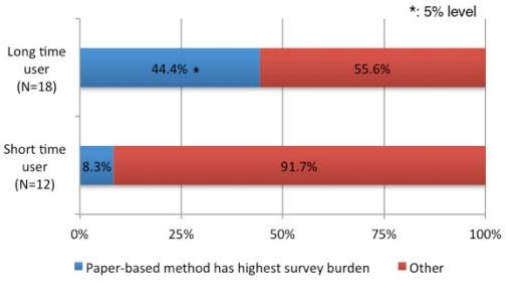


(c) Paper-based record students group

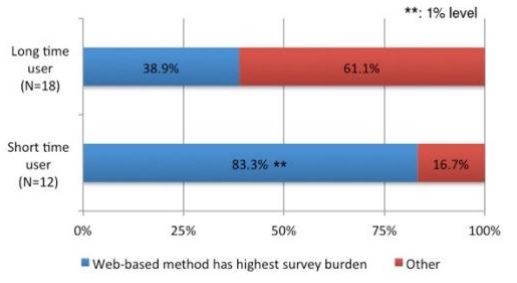


(d) Web-based record students group

Fig. 10. Time difference between smartphone-based and self-reporting survey by internet use time



(a) Paper-based



(b) Web-based

Fig. 11. Survey burden difference between smartphone-based and self-reporting survey by internet use time

4. Summary of Findings

This study intended to reveal the difference between the paper- and web-based travel survey results. The focus was on the error in the departure or arrival time of the trips reported by the participants. We conducted paper-, web-, and smartphone-based surveys using the same formats in the 2012 Kumamoto PT Survey. The recorded time of the smartphone-based survey was assumed to be accurate, and we investigated time difference between smartphone-based and self-reporting (paper-based/web-based) survey results. We have the following findings from the surveys:

(1) The burden of paper-based survey affected the time difference between the smartphone-based and self-reporting survey results.
(2) Elapsed days to record affected the time difference, particularly in the web-based survey.
(3) Young long-time internet users produced large time difference.

Finding (1), (2) implies the importance of designing the survey format such that the participants feel little burden. Finding (3) suggests the necessity to ask the participants to record immediately, particularly in the web-based survey.

One limitation of our study is small number of participants. Our participants had to report paper- and web-based survey along with smartphone-based survey. Thus, it is not easy to recruite many participants in our survey with high survey burden. In our future study, we will try to collect various participants and find more significant findings.

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