Are self-reported times rounded? Insights from times reported by an objective third party

Sanko, Nobuhiro

Iriguchi, Naotaka

(Citation)
Transportation Research Interdisciplinary Perspectives,16:100698

(Issue Date)
2022-12

(Resource Type)
journal article

(Version)
Version of Record

Transportation Research Interdisciplinary Perspectives 16 (2022) 100698

Contents lists available at ScienceDirect

Transportation Research Interdisciplinary Perspectives

journal homepage: www.sciencedirect.com/journal/transportation-research-interdisciplinary-perspectives

Are self-reported times rounded? Insights from times reported by an objective third party

Nobuhiro Sanko [a,*], Naotaka Iriguchi [b]

[a] Graduate School of Business Administration, Kobe University, Japan
[b] School of Business Administration, Kobe University, Japan

ARTICLE INFO

Keywords:
Rounding error
Travel survey
Departure time
Arrival time
Objective data collection
Self-report

ABSTRACT

Data reported by respondents often include rounding errors. In travel surveys, people do not report their exact departure or arrival times, and they often round the times to nearest multiples of 5, 10, 15, 30, and 60 min. Previous studies have estimated rounding probabilities by assuming that while the actual times are evenly distributed between 0 and 59 min, the reported times are rounded. However, no studies have confirmed this assumption that actual times are evenly distributed. The present study aims to confirm the assumption by utilising times reported by a third party. The data come from the Japanese Prime Minister's minute-by-minute activity schedule published daily in newspapers. The data covers 90 days between 27 June and 24 September 2021. The present study confirmed that times relating to travel (departure and arrival times) were evenly distributed. However, times relating to some non-travel behaviours were not evenly distributed. The study supports the assumption that departure and arrival times are evenly distributed, but researchers must consider the nature of the events.

1. Introduction

Data is essential for any analysis. Various data collection methods are available, each with its own merits, and researchers must choose the method that fits their research aims. Furthermore, when the data collected using the selected method might include errors, researchers sometimes develop models to address the errors. Therefore, researchers must understand the nature of the data collected by different data collection methods.

The present study examines the self-report method. This method is frequently utilised in many disciplines, for example, for household travel surveys, which are conducted in many countries. Most of the collected data come from self-reports, for example, the respondents fill in specific forms or answer questions over the telephone. The most significant merit of the self-report method is its ease. Researchers simply ask the respondents questions, and data collection requires only paper and pencil. However, the self-report method has one serious issue: rounding.

Rounding is frequently observed in travel surveys. In these surveys, the times reported for departure and arrival have peaks at multiples of 5, 10, 15, 30, and 60 min. For example, people who leave home at 6:58 a.m. may report their departure time as 7:00 a.m. In other words, a reported 7:00 a.m. departure time does not necessarily mean that the respondent departed at 7:00 a.m. Respondents might use rounding because 1) They might not remember their exact departure times, especially when filling in the questionnaire form at the end of the day or on the following day, 2) They do not realise that the surveyors want them to report exact times without rounding, or 3) They fill in the questionnaire for other household members and do not know the exact times.

Moreover, the nature of rounding may differ among respondents. For example, some might round to the nearest 5 min while others might round to the nearest 15 min. Contexts (business, leisure), events (travelling, meeting, dining), and culture (the nearest quarter-hour is more common in some cultures) also might affect rounding. Rounding is inevitable in household travel surveys and other surveys that ask for numeric information, such as age (Heitjan and Rubin, 1990), vehicle kilometres travelled (Yamamoto et al., 2020), income (Zinn and Würbach, 2016), and work hours (Otterbach and Sousa-Poza, 2010). Analysing rounded data as if the numbers were not rounded can have serious consequences (Rietveld, 2002).

Rietveld (2002) is one of the earliest and most important studies to address rounding. The study proposed a model for estimating the probabilities of rounding by making two assumptions: 1) The actual times are distributed evenly between 0 and 59 min, and 2) The reported

* Corresponding author.

https://doi.org/10.1016/j.trip.2022.100698
Received 5 June 2022; Received in revised form 29 September 2022; Accepted 12 October 2022
Available online 20 October 2022

times might or might not be rounded. The estimates produced by the model seem intuitively reasonable and help explain the rounding. However, the first assumption—actual times are evenly distributed—has never been confirmed.

This study aims to confirm the assumption that actual times are evenly distributed by utilising a unique and ideal dataset of times that are objectively observed and reported by a third party. This data consists of the Japanese Prime Minister's daily schedule that is published daily in newspapers. The third party in this context is newspaper journalists. They objectively observe and record the Prime Minister's activities minute-by-minute in real-time. Because their primary concern is recording objective and accurate information, they have no reason to use rounding. Furthermore, the observations are in real-time, and there is no chance that someone will forget the times.

This paper is organised as follows. Section 2 reviews the relevant literature and presents the contributions of this study, Section 3 describes the data, Section 4 reports the results, and Section 5 discusses the implications of the findings and presents the conclusion.

2. Literature review

Rounding errors are observed in various self-report surveys, including transport surveys. Because these errors can significantly impact the results of analyses, many studies have been conducted to understand rounding errors. The authors have identified two strands of research into rounding.

The first strand of research utilises data after rounding and estimates models to explain how the data was rounded. One of the earliest studies, Rietveld (2002), analysed departure and arrival times in the annual national transport survey in the Netherlands in 1997. The reported times occur much more frequently at multiples of 5, 15, 30, and 60 min. Rounding probabilities were formulated for the nearest multiples of 5, 15, 30, and 60 min, and the interval between the actual time and the target of rounding was assumed to affect the probability. For example, a 24-minute time has a 1-minute interval to the nearest multiple of 5 min (i.e., 25 min). This time is more likely to be rounded than a 23-minute time that has a 2-minute interval to the nearest multiple of 5 min. These estimates seem reasonable from an economic perspective.

Sato and Maruyama (2020) applied Rietveld's rounding error probability model to household travel survey data collected in Kumamoto, Japan, but made two changes to the model. First, the probabilities of rounding were formulated to the nearest multiples of 5, 10, 15, 30, and 60 min, adding a multiple of 10 min to the model since it was frequently observed in the dataset. Second, the interval to the rounding target was considered only for the nearest multiples of 5 min, although Rietveld's model estimated the intervals to the other multiples. As a result, Sato and Maruyama's model outperformed Rietveld's model for their dataset, suggesting that times are rounded in different manners in different cultures. The study further analysed the nature of rounding in different contexts and found that males, the elderly, and frequent travellers (those with a larger number of trips per day) tend to round reported times.

The two studies described above carry a warning: their data includes only times after rounding, and the actual times before rounding are unknown. In addition, the studies make two fundamental assumptions: the actual times are evenly distributed across the 0–59 min range, and each minute has different rounding characteristics. Although the rounding characteristics are formulated and estimated, the assumption that the actual times are evenly distributed has not been confirmed.

The second strand of research attempts to collect data before rounding. The use of mobile devices, such as GPS terminals and mobile phones, has become technologically and economically more accessible these days. Moreover, carrying the devices is less burdensome for respondents, and the devices transmit information about locations and times at certain time intervals and/or at predetermined occasions. Although the resolution of the devices may be a concern with respect to both space and time, even when the trajectory of respondents in the time–space dimension is perfectly observed and has negligible small transmission intervals, the start and end of a behaviour are not clearly identified. The departure and arrival times of trips that include spatial movements are easier to identify. In contrast, other behaviours that do not necessarily involve spatial movements, for example, meetings and phone calls, are much more difficult to identify. Murakami and Wagner (1999) placed GPS devices in private cars to obtain accurate travel information. Respondents also were asked to recall their travel behaviours by telephone. This latter data may include rounding. While the departure times recalled have peaks at multiples of 15 min followed by smaller peaks at multiples of 5 min, the data reported by GPS shows no such peaks and is almost evenly distributed throughout the hour. This American study shows a tendency to round to the nearest 15 min.

The ultimate solution is to have respondents carry cameras and record their lives for 24 h daily (Kelly, 2013). Researchers then browse the images and identify the respondents' behaviours. However, this method is unrealistic for two reasons. First, people would not accept being having their lives recorded 24 h a day. Second, researchers would need considerable time to process the data. In addition, some difficulties in coding are reported (Kelly et al., 2015).

This study aims to verify that the start and end times of behaviours are evenly distributed across a range of minutes, as assumed in the first strand of research. Although mobile devices are useful for collecting accurate data, as described in the second strand of research, there is no better method of recording behaviours than for humans to observe the behaviours in the field. Self-reporting and objective third-party reporting are similar in the sense that the reporters are human beings. This similarity has merits for evaluation purposes if both generally report rounded minutes. Ideal data about the Japanese Prime Minister's behaviours is available from published newspaper articles. Newspaper journalists record the behaviours in real-time, and their primary interest is recording accurate information. They have no intention to round and no possibility of forgetting the exact times. The journalists themselves observe the behaviours with their own eyes, and there is no need to identify behaviours based on collected data, which is a problem when using mobile devices. Furthermore, the behaviours are published, the respondents need not wear cameras, and researchers need not browse the images. Note that the present study looks only at times reported by objective third parties and does not compare those times to times reported by respondents.

3. Data

This study examined published newspaper articles of the Japanese Prime Minister's activities. Most major newspapers in Japan publish descriptions of the Prime Minister's activities on the previous day. The articles are minute-by-minute records of the activities, including when and where the Prime Minister departs and arrives as well as when, for what purpose, and with whom the Prime Minister meets.

The Prime Minister's activities are recorded by political correspondents from major media companies, including NHK (Japan Broadcasting Corporation) (NHK, 2018), Jiji Press (JIJI.COM, 2021e), and Kyodo News (47NEWS, 2022). For example, the Jiji Press has six correspondents (Jiji Press, 2022) attached to the Prime Minister's beat. They follow the Prime Minister and record all activities 365 days a year, from leaving the Prime Minister's residence in the morning to returning to it at night. They also ask visitors the purpose of their meeting with the Prime Minister. The times are cross-checked by correspondents from the Jiji Press and Kyodo News (47NEWS, 2022). The times and activities are then published the following day in newspapers.

A unique feature of the data about the Prime Minister's daily activities is that a third party collects it. The data is objectively recorded in real-time, and the times are accurate. Recording accurate information is a primary interest for the media, and there is no incentive to round times.

The present study utilised articles published by the Jiji Press. The authors assessed four other major newspapers—The Mainichi Shimbun, The Nihon Keizai Shimbun, The Asahi Shimbun, and The Yomiuri Shimbun—and found that the Jiji Press published the most detailed information, reporting the departure and arrival times for travel as well as the start and end times for non-travel.

Table 1 presents data from an article published by the Jiji Press that described the Prime Minister's activities on 22 September 2021 (JIJI.COM, 2021d). The data in columns Times and Descriptions have been slightly modified (for example, excluding personal names irrelevant to the purpose of study). Records are divided into 1: Travel and 0: Non-travel (see the Behavioural class column), and minutes are recorded in Travel Departure, Travel Arrival, Non-travel Start, and Non-travel End. Transportation often is considered to be derived demand, and the descriptions in the articles show this. For example, the article mentions '10:04–10:12 Meeting' but does not mention '7:51–7:56 Travel'. Therefore, non-travel behaviours often include both the start and end times in a single row. This does not apply to travel behaviours.

The authors further classified Non-travel into seven subclasses: 2: Meetings, 3: Conferences, 4: Press interviews, 5: Dining, 6: Private business, 7: Online conferences, and 8: Ceremonies and events. Meetings are identified with statements that include personal names, while conferences are identified with statements that include the conference names but not the names of the participants. Cabinet meetings are listed under 3: Conferences. This study distinguishes between face-to-face conferences and online conferences. Since the spread of COVID-19, online conferences (including telephone calls, teleconferences, and online meetings) are much more common; this study examined the differences in times between these conference formats. In this study, conferences refer to face-to-face formats unless otherwise noted. Private business refers to the Prime Minister's personal matters, such as dental clinic appointments, medical check-ups, and haircuts. For some personal matters, particularly private business, the starting time will be reported, but the end time may not be reported. Personal matters outside of these subcategories have been removed from the analysis.

This study collected data for 90 days, from Sunday 27 June to Friday 24 September 2021 (JIJI.COM 2021a, 2021b, 2021c, 2021d). A total of 2054 times were reported (716 for travel and 1338 for non-travel).

4. Results

4.1. Overall results

Fig. 1 shows the number of time datapoints reported for Travel (departure + arrival), Travel (departure), Travel (arrival), Non-travel (start + end), Non-travel (start), and Non-travel (end) across a range of 0–59 min (black bars indicate minutes for multiples of 5 min). Fig. 1(a)–(c) present travel-related data. While no notable peaks appear at multiples of 5, 10, 15, 30, and 60 min, the 50–59 min range frequently has more data. On the other hand, the non-travel data in Fig. 1(d)–(f) show distinctive patterns. Higher peaks appear at multiples of 10 min and slightly higher peaks at multiples of 15 min; this is more apparent in Fig. 1(e) Non-travel (start).

A goodness-of-fit test was conducted to evaluate how well the distributions of the observed values and expected values match. The null hypothesis H_0 is described as follows.

H_0: The time (in minutes) at which the behaviour observed (reported in the present context) is evenly distributed over the 60 min.

The test statistic, defined by Eq. (1), follows a chi-squared

Table 1
Description of Prime Minister's movements on 22 September.

Times	Descriptions[a]	Behavioural class[b]	Non-travel sub-class[c]	Minutes			
				Travel		Non-travel	
				Dep.	Arr.	Start	End
7:51	Left the Dormitory for Members of the House of Representatives at Akasaka, Tokyo	1		51			
7:56	Arrived at the Prime Minister's Office; Walked around the grounds of the Office	1			56		
10:04–10:12	Meeting with the President of the Japan Bank for International Cooperation*; Special Advisor to the Prime Minister*	0	2			4	12
10:15–10:50	Meeting with the Minister of the Environment*	0	2			15	50
10:57–11:10	Meeting with the Chairperson, Public Relations Headquarters, Liberal Democratic Party*	0	2			57	10
14:30–14:53	Interview with Bloomberg, USA	0	4			30	53
15:05–15:13	Meeting with the Administrative Vice-Minister of Defense*	0	2			5	13
15:20–15:47	Meeting with Deputy Chief Cabinet Secretary*; Secretary-General of National Security Secretariat*; Special Advisors to the Prime Minister**; Deputy Minister for Foreign Affairs*; Director-General, International Cooperation Bureau, Ministry of Foreign Affairs*; Director-General, Global Issues, Ministry of Foreign Affairs*; Vice-Minister of Finance for International Affairs*; Vice-Minister for International Affairs*; Vice-Minister for International Affairs, Ministry of Land, Infrastructure and Transport*; Vice-Minister for Global Environment, Ministry of the Environment*; Vice-Minister of Defense for International Affairs*	0	2			20	47
16:22	Left the Prime Minister's Office	1		22			
16:26	Arrived at the West Wing of the Zenkoku Chousonkaikan at Nagata-cho, Tokyo; Condolence visit for the former Chairman of the Liberal Democratic Party*	1			26		
16:30	Left the place mentioned above	1		30			
16:33	Arrived at the Prime Minister's Office	1			33		
17:00–17:52	Meeting with Minister of Health, Labour and Welfare*; Minister of Land, Infrastructure, Transport and Tourism*; Chief Cabinet Secretary*; Minister in charge of Economic Revitalization*; Assistant Chief Cabinet Secretary*; Special Advisor to the Prime Minister*; Head, Office for COVID-19 and Other Emerging Infectious Disease Control, Cabinet Secretariat, Government of Japan*; Deputy Director-General, Office for COVID-19 and Other Emerging Infectious Disease Control, Cabinet Secretariat, Government of Japan*; Vice-Minister of Health, Labour and Welfare*; Chief Medical and Global Health Officer, Ministry of Health, Labour and Welfare*	0	2			0	52
18:08	Left the Prime Minister's Office	1		8			
18:10	Arrived at the Second Members' Office Building of the House of Representatives	1			10		
19:04	Left the place mentioned above	1		4			
19:12	Arrived at the Dormitory for Members of the House of Representatives at Akasaka, Tokyo	1			12		
22:00	Stayed at the place mentioned above	0					

[a] Personal names are replaced with asterisks. The number of asterisks corresponds to the number of people.
[b] 1: Travel-related; 0: Non-travel related.
[c] 2: Meetings; 3: Conferences; 4: Press interviews; 5: Dining; 6: Private business; 7: Online conferences; 8: Ceremonies and events.

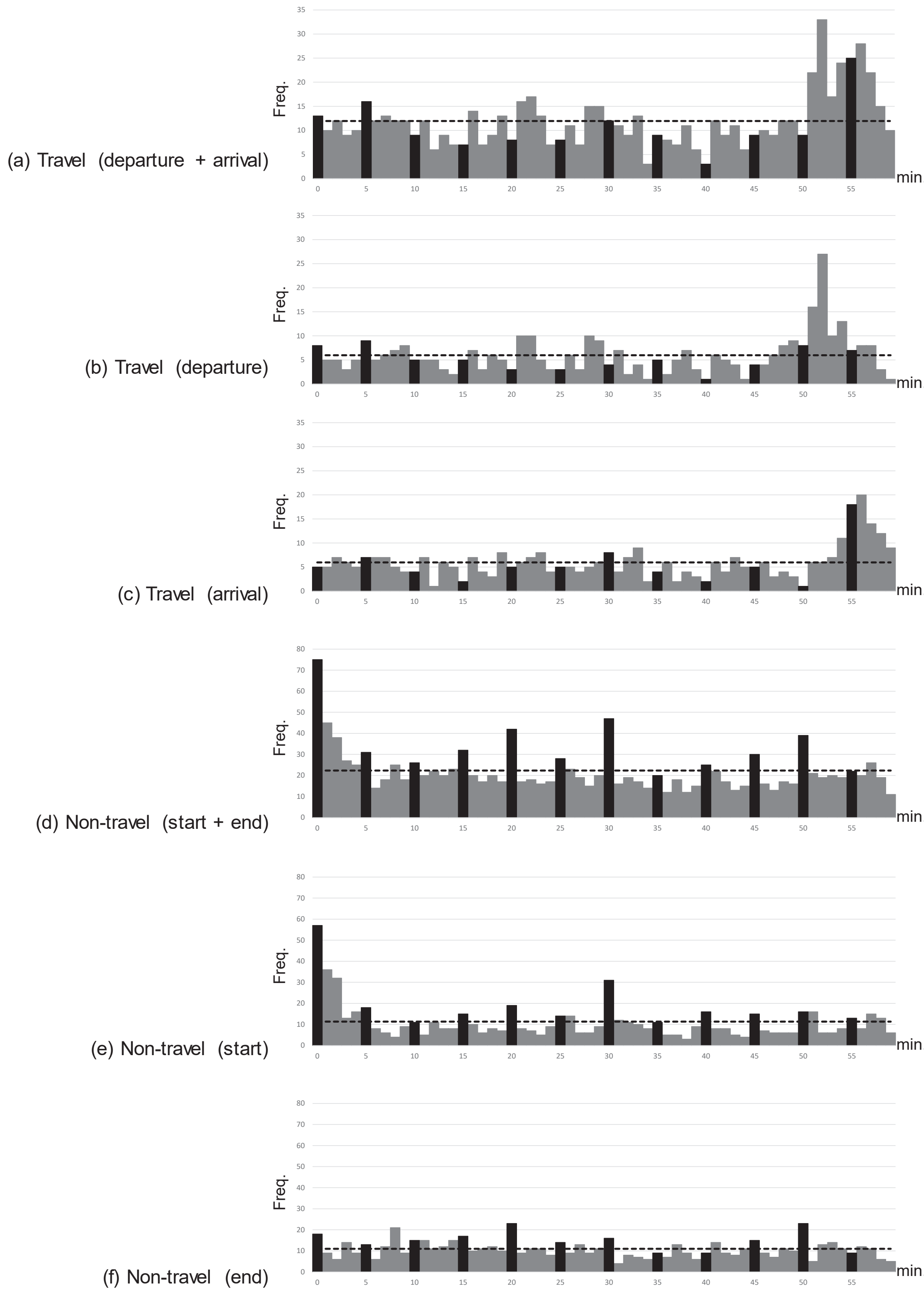

Fig. 1. Distribution of times by categories over 0–59 min range. Note: Dashed lines indicate expected frequency.

distribution. Since the number of categories is $k = 60$ (0–59 min), the degree of freedom is $60 - 1 = 59$. A critical value for a one-sided test at a 5 % level of significance with 59 degrees of freedom is 77.931.

$$X^2 = \sum_{n=1}^{k} \frac{(n_i - E_i)^2}{E_i} \quad (1)$$

where n_i and E_i are the observed and expected frequencies for the i-th category, respectively.

Table 2 reports that all test statistics are greater than 77.931, meaning the null hypothesis is rejected.

For non-travel related times (Table 2(d)–(f)), the null hypothesis is

Table 2
Goodness-of-fit tests over 0–59 min range.

	(a) Travel (Dep. + Arr.)	(b)Travel (Dep.)	(c)Travel (Arr.)	(d) Non-travel (Start + End)	(e)Non-travel (Start)	(f)Non-travel (End)
Chi sq. values	159.698	162.894	118.313	290.969	408.549	90.000
p-value	0.000***	0.000***	0.000***	0.000***	0.000***	0.006***
n	716	358	358	1338	678	660

Note: Critical value for a 5 % level of significance with 59 degrees of freedom is 77.931.
* $p<.10$, ** $p<.05$, *** $p<.01$.
The *p*-value presented is calculated from the asymptotic chi-squared distribution of the test statistic. Level of significance indicated by asterisks does not change when the *p*-value is calculated by Monte Carlo simulation.

rejected. The chi-squared value of 408.549 is extremely large for Non-travel (start). As Fig. 1(e) shows, higher peaks appear at multiples of 10 min, and the observed frequency at 0 min is around five times greater than the expected frequency.

For travel-related times (Table 2(a)–(c)), the null hypothesis is rejected. While Fig. 1(a)–(c) reveal higher frequencies in the 50–59 min range, the data counts are evenly distributed for the rest of the minutes. A closer look at the original data in the 50–59 min range reveals that many of the travel-related activities at the corresponding minutes were for the daily routine of travel from the Dormitory for Members of the House of Representatives to the Prime Minister's Office. The Prime Minister then walks around the grounds of the Office. This habitual daily activity may cause an uneven distribution of travel-related times. Departure and arrival times are examined for each hour and each trip purpose (commuting to work, business, free, and going home). Some clusters are observed for departure and arrival times between 7:00–7:59 a.m. and commuting to work purposes, both of which overlap the routine travels discussed here. Departure and arrival times in the other hours and the other trip purposes do not have any big clusters in the dataset. Therefore, the present study continues to focus on the routine travels as a source of the uneven distribution.

4.2. Results without routine travels

The null hypothesis that travel-related times are evenly distributed over the 0–59 min range was rejected in Section 4.1 due to the greater number of routine travel events at around 7:50 a.m. However, dense distribution in the 50–59 min range seems irrelevant to rounding. Rounding errors must have big clusters at nicely rounded minutes. However, the frequency is highest at 52 min in Fig. 1(a) and (b) and at 56 min in Fig. 1(c), neither of which are nicely rounded minutes. Fig. 1(a)–(c) have no rounding errors but just big clusters.

Routine travel from the Dormitory for Members of the House of Representatives to the Prime Minister's Office at around 7:50 a.m. was removed for this analysis. Times for routine travel fluctuate to a small degree. Therefore, the corresponding travel-related times that are slightly earlier than 7:50 a.m. and later than 8:00 a.m. also were removed. Fig. 2 shows the distribution of the data counts. Peaks in the 50–59 min range are no longer apparent, and it is now clear that the uneven distribution observed in Fig. 1(a)–(c) can be ascribed to habitual behaviour. The goodness-of-fit test was carried out in the same manner. Table 3 shows the results. All test values are smaller than 77.931, and the null hypothesis is not rejected at a 5 % level of significance.

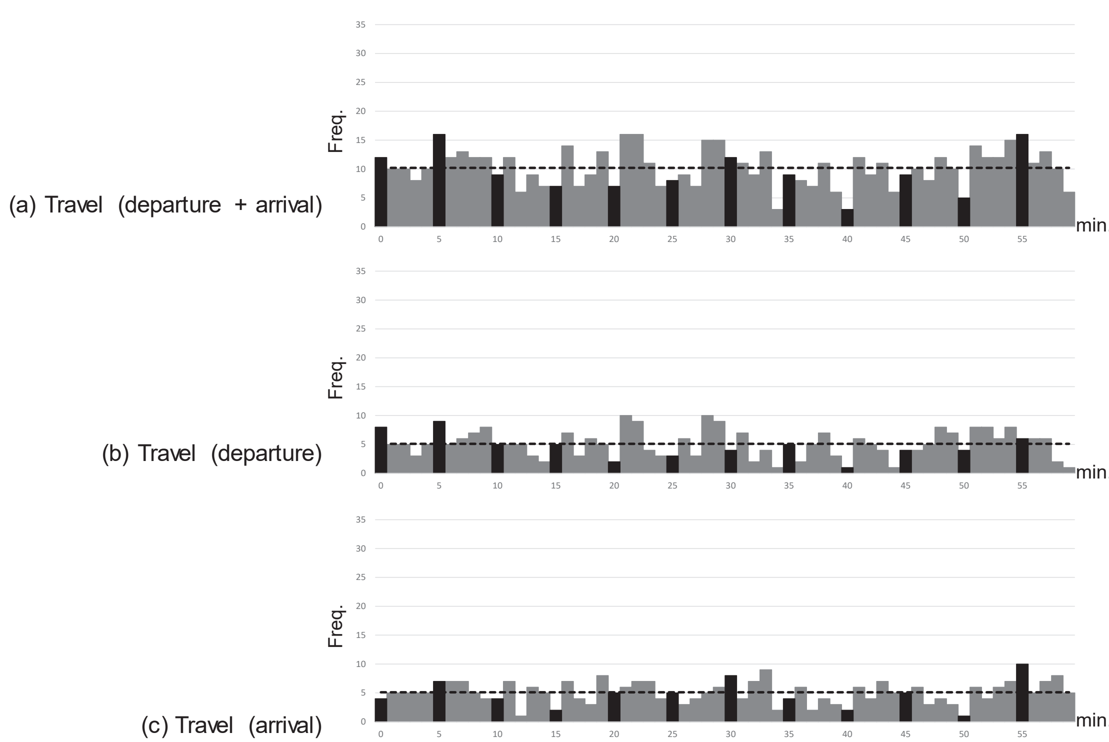

Fig. 2. Distribution of times by categories over 0–59 min range (without habitual behaviours). Note: Dashed lines indicate expected frequency.

Table 3
Goodness-of-fit tests over 0–59 min range (without habitual behaviours).

	(a) Travel (Dep. + Arr.)	(b)Travel (Dep.)	(c)Travel (Arr.)
Chi sq. values	59.176	63.412	43.020
p-value	0.469	0.324	0.941
n	612	306	306

Note: Critical value for a 5 % level of significance with 59 degrees of freedom is 77.931.
* $p < .10$, ** $p < .05$, *** $p < .01$.
The *p*-value presented is calculated from the asymptotic chi-squared distribution of the test statistic. Level of significance indicated by asterisks does not change when the *p*-value is calculated by Monte Carlo simulation.

4.3. Results concerning the last digit

The problem of routine travel in the 50–59 min range is addressed by focusing on the last digit of minutes. The greater numbers of observations in the 50–59 min range are not nicely clustered around rounded minutes (i.e., 50 and 55 min), which leads to the assumption that the times are evenly distributed with respect to the last digit even when the data includes routine travel. Data for 0, 10, 20, 30, 40, and 50 min are combined as minute 0, data for 1, 11, 21, 31, 41, and 51 min are combined as minute 1, and so forth. This method is superior to that in Section 4.2 with respect to utilising the larger number of observations. However, it is inferior when the targets of rounding are not limited to 5 and 10 min (i.e., 15, 30, and 60 min).

Fig. 3 presents the distribution of data counts. Table 4 shows the goodness-of-fit test results from Eq. (1). Note that the number of categories is $k = 10$ (0–9 min), and the degrees of freedom is calculated as $10 - 1 = 9$. A critical value for a one-sided test at a 5 % level of significance with 9 degrees of freedom is 16.919.

Fig. 3(a)–(c) suggest that travel-related times are evenly distributed, while Fig. 3(d) and (e) indicate that non-travel related times are unevenly distributed. Fig. 2(f) is ambiguous. The goodness-of-fit tests in Table 4 also confirm this. The test values are smaller than 16.919 for Travel (departure + arrival) and Travel (arrival), while they are larger than 16.919 for the other categories. However, the value for Travel (departure) was 22.000, which is slightly larger than the critical value for a 1 % significance value of 21.666. On the other hand, chi-squared test values for the other behaviours exceed the critical value quite significantly, with a large number of data counts having zero as the last digit. Figs. 2 and 3 are similar for travel, while Figs. 1 and 3 are similar for non-travel.

4.4. Non-travel behaviours with finer classifications

Thus far, non-travel activities have been placed in a single category. This section analyses non-travel activities with seven classifications that are defined in Section 3. The evenness of distribution in times was tested with respect to the last digit since each subcategory's start and end times sometimes have less than 60 observations, which is not suitable for analysing distribution over the 0–59 min range.

The distributions of the data counts in each subcategory's start and end times are presented in Fig. 4. The goodness-of-fit test defined in Eq. (1) is performed, and the results are shown in Table 5. The critical value for the one-sided test at a 5 % level of significance with 9 degrees of freedom is 16.919. The table reveals that the test statistics have greater values for the start times than for the end times for all activities except Table 5(c) Press interviews. The start times for Table 5(a) Meetings, (b) Conferences, and (f) Online conferences have extremely large test values. The start times for meetings and conferences tend to be fixed at nicely rounded minutes, but the end time depends on the content of the meeting or conference. This tendency is supported by larger data counts for 0 min in Fig. 4(a) and (f). However, the start times in Fig. 4(b) Conferences are much more frequently delayed by 1 and 2 min for unknown reasons. Fig. 4(f) shows that 17 out of 27 counts are observed at 0 min. In online meetings and conferences, the Prime Minister often talks with heads of states and municipalities in teleconferences, the timing of which must be determined and arranged by the staff at nicely rounded minutes.

4.5. The nature of evenly-distributed travel-related times

This section returns to travel-related times and discusses factors behind the evenly distributed travel-related times.

Times relating to travel are not exactly fixed in the order of minute before departures and arrivals. Even when people depart or arrive, people do not care about times in minutes very much. Due to its nature of derived demand of travel, departure and arrival times are determined by constraints relating to other than travel itself. Typical constraints are appointments at destinations.

Suppose an individual has a meeting at 9:00 a.m. at a location 10 min from their home on foot. The individual may think of departing at around 8:45 a.m. considering the walking time of 10 min and a buffer of 5 min. Note that the walking time of 10 min is just their estimate. However, this does not necessarily mean that the individual will decide to depart at exactly 8:45 a.m. and arrive at exactly 8:55 a.m. The individual does not care about leaving (and arriving) slightly earlier or later as long as they arrive at the meeting place before the meeting starts. A late departure occurs quite frequently when, for example, a phone call is received just before the departure.

Even when the individual departs at a nicely rounded minute, they do not arrive at a nicely rounded minute because walking times are not always nicely rounded in the order of minutes. Meeting places differ, and it is rare for departure, travel, and arrival times to always be in nicely rounded minutes. Even walking times in the same origin–destination pairs differ due to the individual's health or the weather that day. The individual may sometimes walk faster or run to ensure a timely arrival. The individual may encounter external factors, such as traffic lights, queuing in front of lifts, or chatting with a colleague that was met by chance. These factors may also influence travelling times.

Finally, some constraints are determined in minutes that are not nicely rounded. One example is a train timetable. Developing a timetable in which all trains depart at all stations at nicely rounded minutes is extremely inefficient. Therefore, a reasonable assumption is that train departures—which are appointments with a train service in the context of this study—are evenly distributed.

5. Discussions and conclusions

Rounding errors in self-report surveys have been considered a source of biases. Examples of rounding are departure and arrival times in household travel surveys. This study utilises accurate times reported by objective third parties to examine whether or not times considered to be rounded in self-reports are rounded. If the rounding often observed in self-reports was not observed in a third-party's report, then the self-report times were rounded. If rounded minutes also were observed in a third-party's report, then the times were not rounded by respondents but were observed at round minutes. Some studies modelled rounding probabilities by assuming that actual times are evenly distributed over the 0–59 min range but rounded when reported. The present study is the first to utilise data collected by a third party to examine the assumption of evenly distributed times. Ideal data is available from newspaper articles that publish the times and behaviours of the Japanese Prime Minister. The present study utilised articles published by the Jiji Press, covering 90 days between 27 June and 24 September 2021.

The behaviours were classified as Travel and Non-travel. Non-travel behaviour was further classified as meetings, conferences, press interviews, dining, private business, online conferences, and ceremonies and events. The results are summarised below.

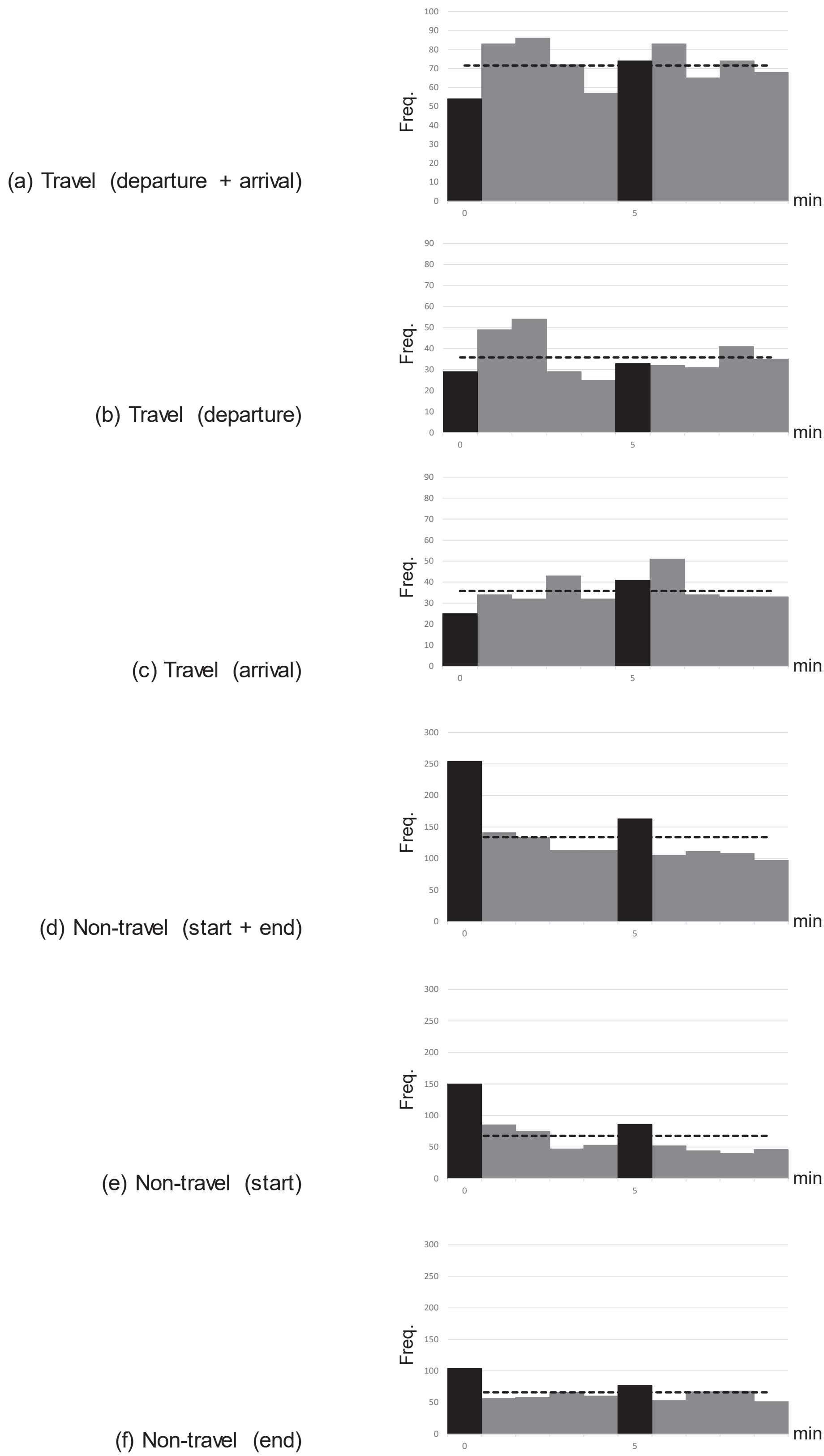

Fig. 3. Distribution of times by categories over 0–9 min range (last digit). Note: Dashed lines indicate expected frequency.

Table 4
Goodness-of-fit tests over 0–9 min range (last digit).

	(a) Travel (Dep. + Arr.)	(b)Travel (Dep.)	(c)Travel (Arr.)	(d) Non-travel (Start + End)	(e)Non-travel (Start)	(f)Non-travel (End)
Chi sq. values	14.782	22.000	13.341	146.395	149.729	32.788
p-value	0.097*	0.009***	0.148	0.000***	0.000***	0.000***
n	716	358	358	1338	678	660

Note: Critical value for a 5 % level of significance with 9 degrees of freedom is 16.919.
* $p < .10$, ** $p < .05$, *** $p < .01$.
The *p*-value presented is calculated from the asymptotic chi-squared distribution of the test statistic. Level of significance indicated by asterisks does not change when the *p*-value is calculated by Monte Carlo simulation.

1. Travel-related times are evenly distributed across the 0–59 min range. Although the Prime Minister's routine trips are clustered in the 50–59 min range, the recorded times are not rounded. After excluding regular trips, the times are evenly distributed across the 0–59 min range; without the exclusion, the times are evenly distributed across the 0–9 min range.
2. Times not related to travel are unevenly distributed across the 0–59 min and 0–9 min ranges. The distribution of times for the start of non-travel behaviours is particularly uneven. This means that, while the start times are predetermined, the adjoining times are not fixed. For example, the adjoining times for conferences depend on the agenda.

The most significant implication for researchers is that the assumption of evenly distributed travel-related times is justified. This paper provides encouraging evidence which supports the assumption relied upon by most previous papers that have analysed rounding errors in self-report surveys. The contribution of this paper is significant since the approach taken is new, meaning that the assumption is supported from greater perspectives. However, the same assumption does not always apply to other behaviours. Some behaviours start and end in rounded minutes, and assuming an even distribution for them is misleading. This study advises caution and concludes that understanding the nature of the activities is essential for analysing rounding.

Although this paper analyses data from Japan, the paper discusses implications for studies in other jurisdictions. Each country or area has its own political system, culture, and customs, which may influence the rounding in each of the following steps (1)–(4).

(1) When scheduling activities.

Meeting times at 00, 15, 30, and 45 min are common in some countries and areas, while meeting times at 00, 10, 20, 30, 40, and 50 min are common in other countries and areas.

(2) When conducting activities.

Meetings always start on time in some countries and areas, while they always start late in other countries and areas.

(3) When recognising times of activities.

In countries and areas where meetings are commonly scheduled at 00, 15, 30, and 45 min, times are also recognised in corresponding minutes. For example, when the exact departure time is 8:59 a.m., it is recognised as 9:00 a.m.

(4) When reporting times of activities.

In countries and areas where meetings are commonly scheduled at 00, 15, 30, and 45 min, times are also reported in corresponding minutes. Even when an individual departs at 8:59 a.m. and they recognise and remember their departure time at 8:59 a.m., the individual will report their departure time as 9:00 a.m.

Applying findings in Japan to countries and areas with different political systems, cultures, and customs must be done with care. Bopp and Faeh (2008), who analysed end-digits preference in self-reported height by different language users, is an example.

The above descriptions can be used to discuss the different characteristics of rounding in different types of activities. Even in the same country or area, customs can differ across organisations or events. Examples include larger data counts for 0 min for meetings and online conferences, as discussed in Section 4.4.

Intentional misreporting, although irrelevant in the present study because of the data used, is a topic of study. One example is the 'lie factor' in traffic safety (Kim, 1999) in which police and hospital records record different seatbelt and alcohol uses. People have incentives to lie to police—falsely reporting that they were wearing a seatbelt and that they had not been drinking alcohol—in order to avoid penalties, while people have disincentives to lie to hospitals. Another example is found in obesity studies in which height is overreported while weight is underreported (Truesdale and Stevens, 2008).

Intentional and unintentional misreporting in the travel survey are discussed with reference to the above (1)–(4). '(1) when scheduling activities' and '(2) when conducting activities' are irrelevant, since rounding errors address errors introduced after conducting the activities regardless of how they are scheduled or conducted. In '(3) when recognising times of activities' and '(4) when reporting times of activities', errors can be introduced both intentionally and unintentionally, although it is difficult to distinguish them.

There is little reason to misreport times of activities with intention. However, people may report incorrect (less precise) minutes in manners they believe to be correct. Respondents may think surveyors do not need times in the order of minutes and will report times after rounding. Researchers themselves are not free from their own belief of rounding. To the best of the authors' knowledge, there are no transportation studies that analyse rounding errors in units smaller than minutes (for example, seconds, deciseconds), implying that researchers consider times reported in minutes to be adequately precise. The authors have never seen survey forms with blanks in units smaller than minutes. There exists a common understanding in use of units in various fields—centisecond for the 100 m run, millisecond for the cycling sprint. However, this has not been discussed in the field of travel survey and is worth investigation. A different understanding in use of units between researchers and respondents may cause uneven distributions.

Preferences to end digits, usually introduced unintentionally, play an important role in (3) and (4) above. It is often the case that respondents do not remember exact times of activities. This is more likely to happen in proxy responses in which another household member fills in the survey form on behalf of the respondent whose activities are not always known to others. If people do not have any preferences for the end digits, there is little reason for non-remembered times to cluster at specific minutes. However, many studies have observed time distributions that suggest an end-digit preference.

The following two cases are examples of either intentional misreporting or intentional adjusting. First, some travel surveys ask

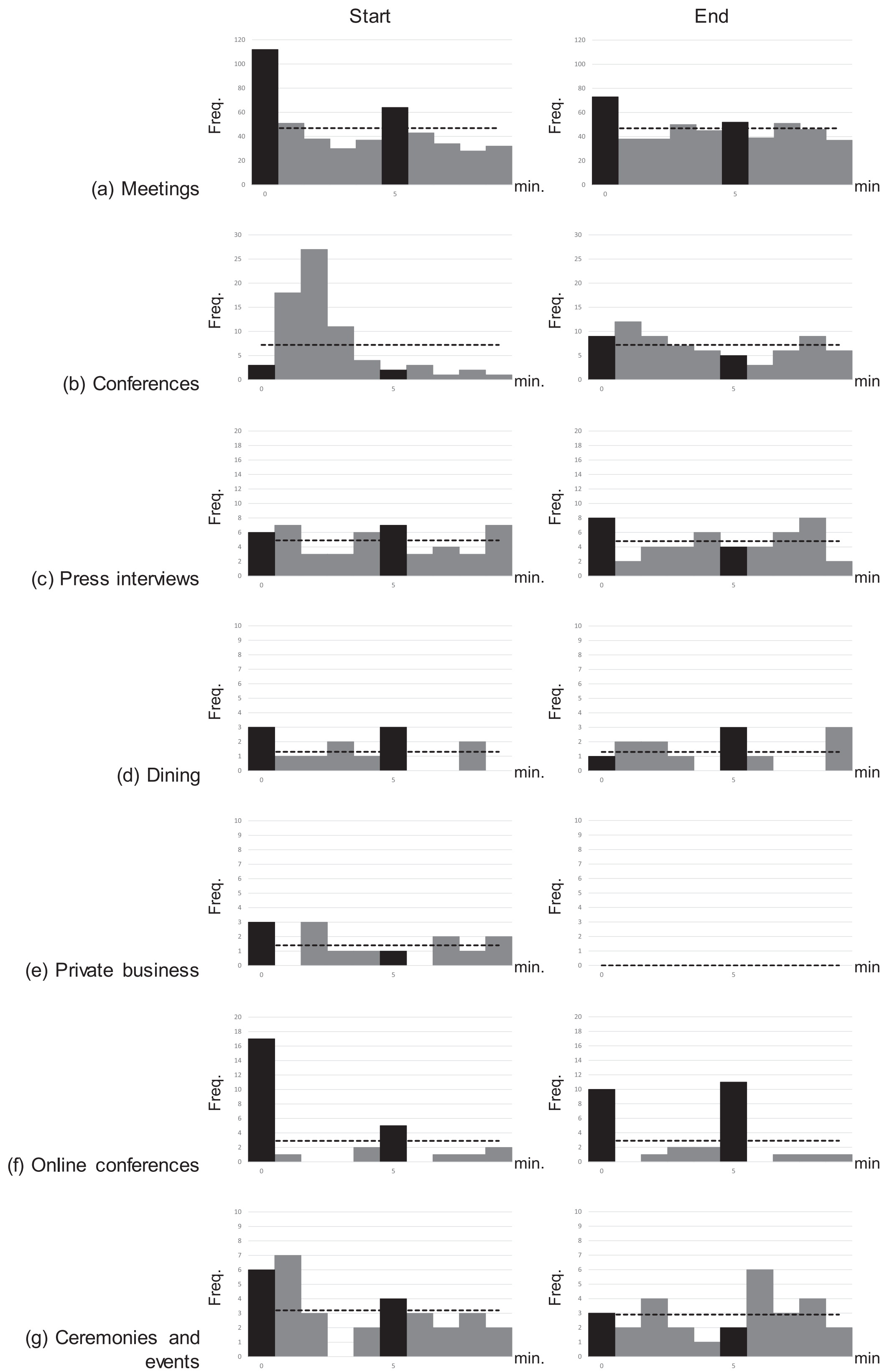

Fig. 4. Distribution of times by non-travel categories over 0–9 min range (last digit), Note: Dashed lines indicate expected frequency.

Table 5
Goodness-of-fit tests over 0–9 min range (last digit) for non-travel subclasses.

	Start			End		
	Chi sq. values	*p*-value	*n*	Chi sq. values	*p*-value	*n*
(a) Meetings	123.047	0.000***	469	22.535	0.007***	469
(b) Conferences	97.167	0.000***	72	8.278	0.506	72
(c) Press interviews	6.306	0.709	49	8.667	0.469	48
(d) Dining	9.308	0.409	13	9.308	0.409	13
(e) Private business	7.429	0.593	14	NA		0
(f) Online conferences	83.069	0.000***	29	51.345	0.000***	29
(g) Ceremonies and events	11.750	0.228	32	6.517	0.687	29

Note: Critical value for a 5 % level of significance with 9 degrees of freedom is 16.919.
* $p < .10$, ** $p < .05$, *** $p < .01$.
The *p*-value presented is calculated from the asymptotic chi-squared distribution of the test statistic. Level of significance indicated by asterisks does not change when the *p*-value is calculated by Monte Carlo simulation.

respondents for not only times of departure and arrival but also times spent for each transportation mode. People may manipulate some of figures to ensure that the sum of times spent for each transportation mode is equal to the time passing from departure to arrival. Second, an actual arrival time of 9:01 a.m. can be misreported at 9:00 a.m. when the respondent has a meeting at 9:00 a.m. and is unwilling to report 9:01 a.m., which would indicate a late arrival.

The most significant limitation of the method proposed in this study is data availability. Although the present study utilises ideal data, collecting similar data for ordinary citizens is extremely difficult. In addition, the lifestyle of the Prime Minister differs from that of the general public, and generalising the findings of the study to the general public should be done with care.

CRediT authorship contribution statement

Nobuhiro Sanko: Methodology, Supervision, Funding acquisition, Conceptualization, Writing – original draft, Writing – review & editing. **Naotaka Iriguchi:** Investigation, Writing – original draft.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data used are included in the paper.

Acknowledgement and/or funding resources

This work was supported by JSPS KAKENHI Grant Numbers 21H01458 and 19K01962. Insightful comments from the editor and reviewers are appreciated and deepened the interpretations and discussions. This paper will be presented at the 66th Infrastructure Planning Conference of the Japan Society of Civil Engineers, Okinawa, Japan, in November 2022.

References

Bopp, M., Faeh, D., 2008. End-digits preference for self-reported height depends on language. BMC Public Health 8, 342.
Heitjan, D.F., Rubin, D.B., 1990. Inference from coarse data via multiple imputation with application to age heaping. J. Am. Stat. Assoc. 85 (410), 304–314.
JIJI.COM. (2021a). https://www.jiji.com/jc/v2?id=ssds202106 (accessed in October 2021). (in Japanese).
JIJI.COM. (2021b). https://www.jiji.com/jc/v2?id=ssds202107 (accessed in October 2021). (in Japanese).
JIJI.COM. (2021c). https://www.jiji.com/jc/v2?id=ssds202108 (accessed in October 2021). (in Japanese).
JIJI.COM. (2021d). https://www.jiji.com/jc/v2?id=ssds202109 (accessed in October 2021). (in Japanese).
JIJI.COM. (2021e). https://www.jiji.com/jc/v4?id=20210611seikaiweb0001 (accessed on 13 March 2022). (in Japanese).
Jiji Press (2022). https://www.jiji.co.jp/recruit/interview/1 (accessed on 13 March 2022). (in Japanese).
Kelly, P., 2013. Assessing the Utility of Wearable Cameras in the Measurement of Walking and Cycling. University of Oxford. Doctoral Thesis.
Kelly, P., Thomas, E., Doherty, A., Harms, T., Burke, Ó., Gershuny, J., Foster, C., 2015. Developing a method to test the validity of 24 hour time use diaries using wearable cameras: a feasibility pilot. PLoS ONE 10 (12), e0142198.
Kim, K., 1999. Lie factor in traffic safety: comparison of police and hospital reporting of seat belt and alcohol use in Hawaii. Transp. Res. Rec. 1665 (1), 141–146.
Murakami, E., Wagner, D.P., 1999. Can using global positioning system (GPS) improve trip reporting? Transp. Res. Part C: Emerg. Technol. 7 (2–3), 149–165.
NHK (2018). https://www.nhk.or.jp/politics/articles/feature/6279.html (accessed on 31 January 2022). (in Japanese).
Otterbach, S., Sousa-Poza, A., 2010. How accurate are German work-time data? a comparison of time-diary reports and stylized estimates. Soc. Indic. Res. 97 (3), 325–339.
Rietveld, P., 2002. Rounding of arrival and departure times in travel surveys: an interpretation in terms of scheduled activities. J. Transp. Stat. 5 (1), 71–82.
Sato, Y., Maruyama, T., 2020. Modeling the rounding of departure times in travel surveys: comparing the effect of trip purposes and travel modes. Transp. Res. Rec. 2674 (10), 628–637.
Truesdale, K.P., Stevens, J., 2008. Do the obese know they are obese? N. C. Med. J. 69 (3), 188–194.
Yamamoto, T., Madre, J.L., de Lapparent, M., Collet, R., 2020. A random heaping model of annual vehicle kilometres travelled considering heterogeneous approximation in reporting. Transportation 47, 1027–1045.
Zinn, S., Würbach, A., 2016. A statistical approach to address the problem of heaping in self-reported income data. J. Appl. Stat. 43 (4), 682–703.
47NEWS, 2022. https://www.47news.jp/7268902.html (accessed on 14 March 2022). (in Japanese).