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Households with every member out-of-home (HEMO): Comparison using the Kumamoto Person Trip surveys in 1984, 1997, and 2012

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Abstract

Most existing studies using a household travel survey have focused on travel behavior, but this study demonstrates another use of it: identifying households with every member out-of-home (HEMO) at a given time. Because a household travel survey records all trips by every member of a household, the calculation of HEMO is not a difficult task, but few studies have shown empirically the temporal rate of HEMOs. This study calculated the HEMO rate as well as the individual out-of-home (IO) rate using a household travel survey, also known as the Person Trip (PT) survey in Japan. Specifically, we compared these rates using the Kumamoto PT surveys in 1984, 1997, and 2012 and discussed the factors for change. The results showed that the HEMO rate has increased considerably, although there was no major IO rate change over 28 years.

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Keywords: Household travel survey, out-of-home rate, redelivery, Kumamoto, Person Trip survey

1. Introduction

1.1. Background and objective

In Japan, the Person Trip (PT) survey has more than 50 years of history as a household travel survey and has contributed to studies in a range of practical and academic contexts. Most existing studies using the PT survey have focused on travel behavior, but the present study focuses instead on out-of-home situations. Because the PT survey records all trips by every member of a household, it enables us to calculate the rate of households with every member

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out-of-home (HEMO) at a given time. Using this information, this study aims to compare and analyze the rates of HEMO gathered via the Kumamoto PT surveys in 1984, 1997, and 2012.

1.2. Literature review

Numerous studies have been conducted using household travel surveys to analyze the travel behavior of individuals and household members. Here we provide a brief review of previous research relevant to our study.

Several studies have examined the reported out-of-home/in-home situation in travel surveys to assess the survey quality. More specifically, they investigate the immobile persons who do not leave their home on a given reporting day. For example, Madre et al. (2007) examined the share of immobile persons to assess the quality of travel diary surveys, because soft refusal can be a cause of immobility or item non-response. They suggest the share of immobile persons should be in the rage of 8-12% for the one-day, weekday-only travel diary. For this investigation, the comparison between travel surveys and other surveys is useful. Hubert et al. (2008) compared the immobility rate between travel diary surveys and time-use surveys in France, Belgium, and the U.K. They found a significant difference in lower immobility rates in time-use surveys indicating soft-refusal in travel diary surveys. Gerike et al. (2015) compared German data sets and found a higher travel estimate by time-use surveys than by travel diaries. They use a generalized additive model for Poisson count data. Motte-Baumvol and Bonin (2018) addressed this issue in the 2008 French Travel Survey. They adopted a structural equation model to examine the lifestyle, occupation, physical, and financial situation of immobility. Richardson (2007) reported interesting results on the rate of immobility by speed of responding (reminder, non-response). The rate of immobility increases as the number of reminders needed for the sample to respond. This is because the reminder regime allows the respondent to choose the travel day.

Time-series analyses of household travel surveys have revealed several interesting findings on travel behavior changes over the years. Kuhnimhof et al. (2012a) compared the trend of young drivers using the national travel surveys from six countries: Germany, France, Great Britain, Japan, Norway, and the U.S.A. They demonstrated that average daily car travel distance has decreased in most countries. Using national travel surveys in Germany, Kuhnimhof et al. (2012b) demonstrated that young males have reduced their car use. McDonald (2015) investigated the travel behavior of young American adults using data from the 1995, 2001, and 2009 National Household Travel Surveys in the U.S. and demonstrated a reduction in youth driving. The trend is also addressed by Garikapati et al.(2016), using the 2003-2013 American Time Use Survey data. Frändberg and Vilhelmson (2011) examined the trend in the Swedish national travel surveys. Buehler and Hamre (2016) examined the multimodal trend using the 2001 and 2009 National Household Travels Surveys in the United States. Hjorthol et al. (2010) examined daily travel by the elderly in the National Travel Surveys in Denmark, Norway, and Sweden from the 1980s to 2006. Choi et al. (2014) examined the change in travel behavior using the 2002, 2006, and 2010 household travel surveys in Seoul, Korea.

Collecting household data enables us to examine the effect of household members. Using the 2008 Nanjing Residents Travel Survey in China, Feng et al. (2013) showed that co-residing with adult children makes the elderly take fewer shorter-distance trips. There is an increasing amount of literature on intra-household interaction modeling using household travel surveys (Bhat and Pendyala, 2005; Ho and Mulley, 2015; Timmermans and Zhang, 2009).

Despite the extensive amount of literature on transportation using household travel surveys, few studies have focused on the out-of-home situation to examine the HEMO rate. Recent research by our research group (Takahashi et al., 2018) presents an examination of HEMO using the Kumamoto PT surveys in 1997 and 2012. The present study extends that research to include the data from 1984. This enables us to investigate three time-series analyses and have a deeper understanding of HEMOs.

2. Method and Data

2.1. Method: Concept and Calculation of HEMO

This study defines “out-of-home time” as the time between the departure from the home and the arrival time when returning home. In addition, we define the HEMO time in which every household member is out-of-home as illustrated in Fig. 1. For a given time-period, individual out-of-home rate (IO rate) is the percentage of individual in out-of-home over the target individual sample, and HEMO rate is the percentage of the household in HEMO over the target household.

This study determines the situation during every 10-minute interval for reducing the computational time. This approximation needs further technical explanation. If the determination timing is the same as the time of departure from home or arrival at home, we determine it as out-of-home. The example is illustrated in Fig. 2. By making a judgment in 10-minute intervals, we ignore home stays of a short time period (2)-(4) and small trips (5). We believe this approximation will not produce a big change in the results. Please note that samples who make no trips on the target day are determined to be in-home during all time periods.

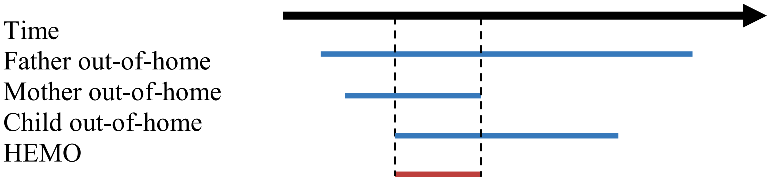
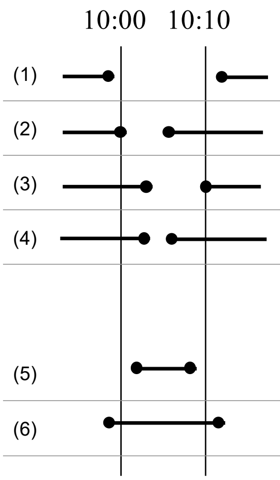


Fig. 1. An illustration of a household with every member out-of-home (HEMO).
Source: Takahashi et al. (2018), modified by the authors.



Arrival at home	Departure from home	10:00	10:10
9:59	10:11	in-home	in-home
10:00	10:05	out-of-home	out-of-home
10:03	10:10	out-of-home	out-of-home
10:03	10:05	out-of-home	out-of-home
Arrival at home	Departure from home	10:00	10:10
10:01	10:09	in-home	in-home
9:59	10:11	out-of-home	out-of-home

Fig. 2. Example of determination of out-of-home periods
Source: Takahashi et al. (2018), modified by the authors.

2.2. Method: Factor Decomposition of HEMO Change

HEMO will change according to several factors. Takahashi et al. (2018) proposed a method to decompose the factors affecting HEMO change over time. Their method, however, has limitation that the result is not intuitively understandable. Thus, we modified their method as bellow.

The two dominant factors affecting HEMO change over time will be:

(a) Changes in the households-type composition,
(b) Changes in the HEMO rate by household-type.

An example of (a) will be an increase in single-person households, and an example (b) will be an increase in the HEMO rate of elderly households. Total HEMO rate is equal to an aggregate of HEMO rate by household-type multiplied by its composition. Thus, the HEMO rate for base year, *R,* is formulated as follows.

$$R = \sum_i r_i o_i, \qquad \sum_i r_i = 1 \tag{1}$$

where r_i is the household composition ratio for household type i and o_i is the HEMO rate by household type i. Here, we omit time of day indexes for simple expression. The HEMO rate for target year, R^*, can be described as follows.

$$R^* = \sum_i (r_i + \Delta r_i)(o_i + \Delta o_i) = \sum_i r_i\, o_i + \sum_i r_i\, \Delta o_i + \sum_i \Delta r_i\, o_i + \sum_i \Delta r_i\, \Delta o_i \tag{2}$$

Then the change in HEMO between the target year and base year is;

$$\Delta R = R^* - R = \sum_i r_i\, \Delta o_i + \sum_i \Delta r_i\, o_i + \sum_i \Delta r_i\, \Delta o_i. \tag{3}$$

Here we define F_O and F_r as factors relating to (a) and (b) respectively as shown below;

$$F_O = \sum_i r_i\, \Delta o_i + \frac{1}{2}\sum_i \Delta r_i\, \Delta o_i \tag{4}$$

$$F_r = \sum_i \Delta r_i o_i + \frac{1}{2}\sum_i \Delta r_i\, \Delta o_i \tag{5}$$

Then, using equations (3), (4) and (5), we decompose the HEMO change by two factors;

$$\Delta R = F_O + F_r \tag{6}$$

For the demonstration, we use the following indexes.

$$RF_O = F_O/\Delta R \times 100, \qquad RF_r = F_r/\Delta R \times 100 \tag{7}$$

$$RF_O + RF_r = 100 \tag{8}$$

Here, RF_O and RF_r represents, respectively, the percentage of the factors caused by change in households-type composition, and those caused by changes in the HEMO rate by household-type.

2.3. Data

We used data from household travel surveys—referred to as Person Trip (PT) surveys in Japan—conducted in 1984, 1997, and 2012 in Kumamoto, Japan. Table 1 shows the outline of each survey. The target area is the Kumamoto Metropolitan area—Kumamoto City and its surrounding areas—and the size of the are covered is almost the same in all three surveys.

If departure or returning home time of a trip is unknown, we cannot calculate the out-of-home time. Thus, the following samples were excluded from the analysis.

- When departure time of the first trip from home is unknown

- When the arrival time from the trip returning home is unknown
- When the departure times of trips following the trip returning home are unknown

Following these criteria, eight samples were excluded from the 1984 data, but none were excluded from the 1997 data. From the 2012 data, 14,817 samples were excluded. The large exclusion of samples from the 2012 data was caused by an error derived from the self-reporting, mail-based response method in the 2012 survey; however, the survey conductor could correct the error in the interview-based methods in the 1984 and 1997 surveys.

3. Results and Discussion

3.1. Individual out-of-home rate and HEMO rate: Overview

Fig. 3 shows the individual out-of-home rate (IO rate) and HEMO rate in three time periods. The IO rate rose greatly around the time of returning home. The HEMO rate rose significantly during the daytime. The rise in HEMO between 1997 and 2012 is large compared to the rise between 1984 and 1997. This result is attributed to the increase in single-person households and females in the labor force in these time periods.

Table 1. Overview of Kumamoto PT surveys

	1984 Kumamoto PT survey	1997 Kumamoto PT survey	2012 Kumamoto PT survey
Survey periods	Oct. 1984	Oct. and Nov. 1997	Oct. and Nov. 2012
Survey Method	Home-based leaving and collecting method	Home-based leaving and collecting method	Mail-based or web-based
Valid sample size	56,996 persons 21,015 households	64,212 persons 25,380 households	82,292 persons 38,337 households

Source: By the authors, based on the report of each PT survey

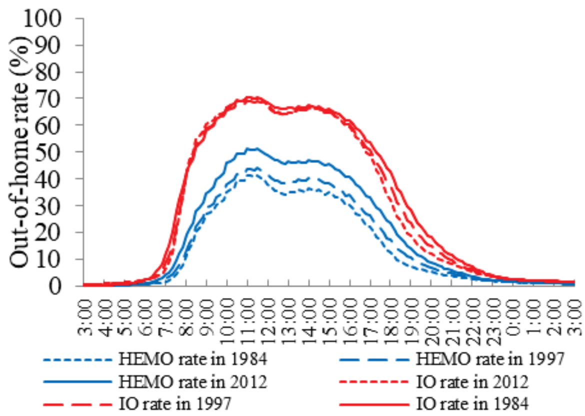
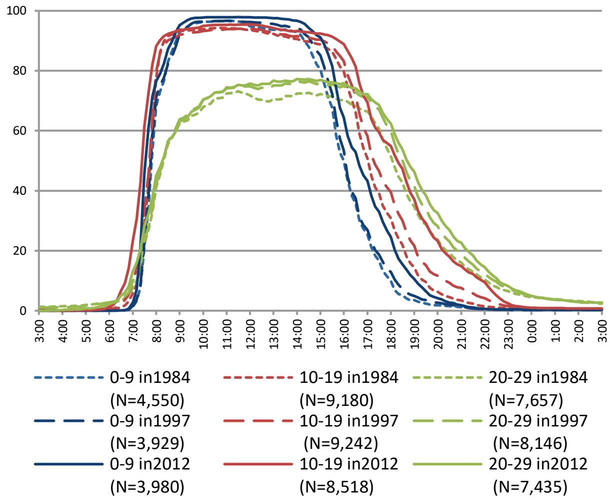
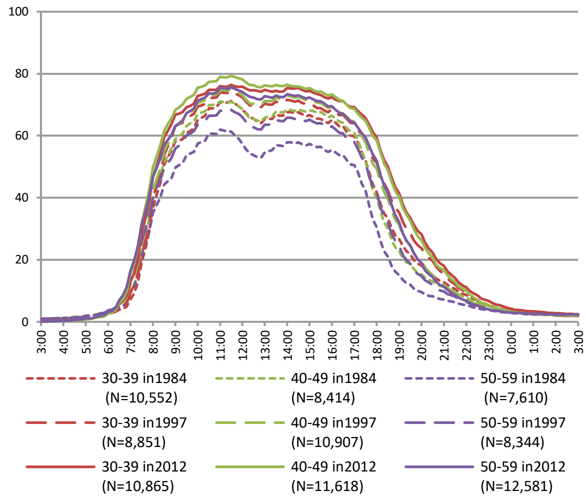


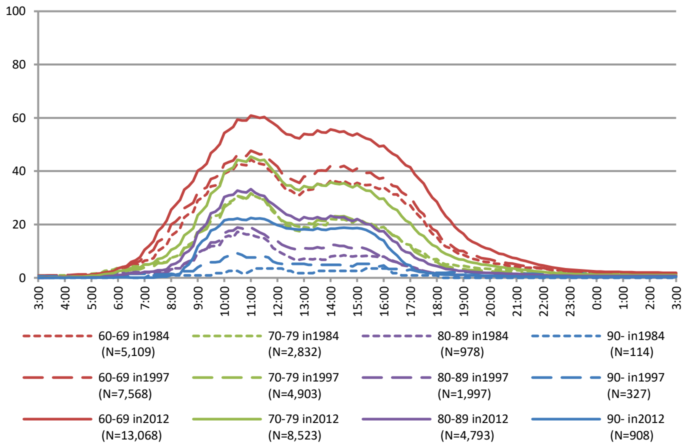
Fig. 3. Change in the individual out-of-home rate (IO rate) and rate of households with every member out-of-home (HEMO rate) between 1984, 1997, and 2012 by the Kumamoto PT survey.



(a) Age 0-29



(b) Age 30-59



(c) Age 60+

Fig. 4. Change in individual out-of-home rate (IO rate) between 1984, 1997, and 2012.

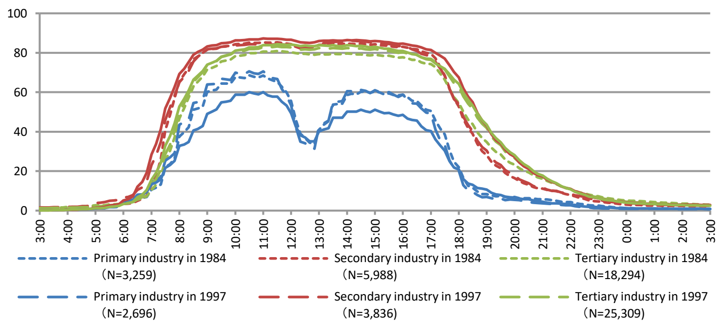


Fig. 5. Change in IO rate by employed industries between 1984, 1997, and 2012.

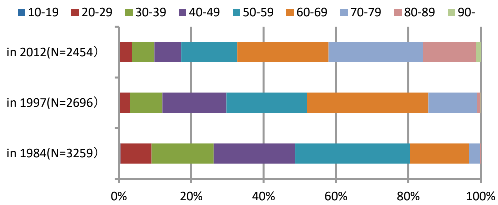
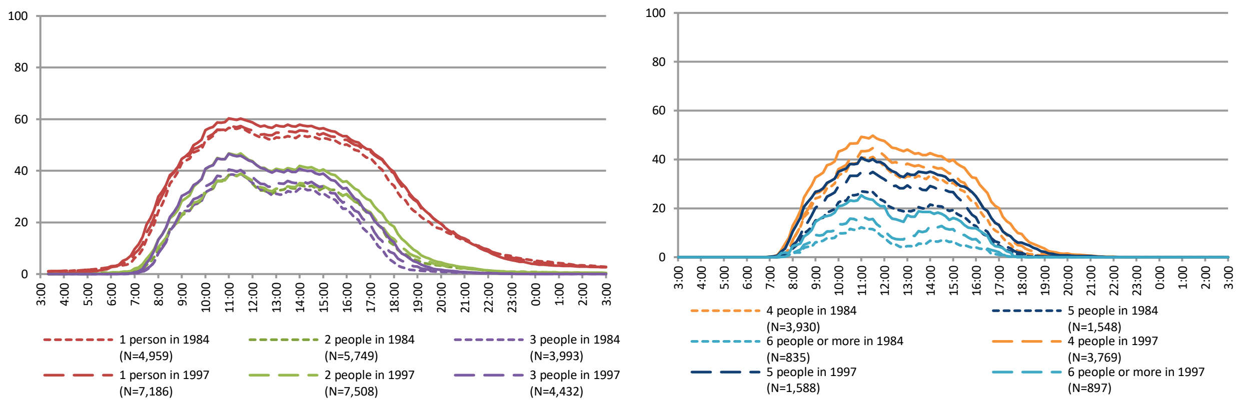


Fig. 6. Change in age distribution of workers in primary industry between 1984, 1997, and 2012.



(a) Household sizes 1, 2, and 3 (b) Household size 4 and over

Fig. 7. Change in HEMO rate by household size between 1984, 1997, and 2012.

3.2. Individual out-of-home rate: Individual characteristics

Fig. 4 demonstrates the IO rate from 1984 to 2012. The IO had risen in almost every age. Fig. 4(a) indicates that the student IO rate is stable during the daytime, but the time of returning home has become late. Remarkable change is observed between 1997 and 2012. The reason could be that students going to cram school increased during these periods. On one hand, the changes between 1984 and 1994 and between 1997 and 2012 are similar in ages 30-59. On the other hand, the change between 1984 and 1994 is small, but a large change between 1997 and 2012 is observed in ages 60 and over. This may be caused by active seniors in these periods.

Fig. 5 shows the IO rate change of workers by employed industries. Little change is observed in the IO rate for the primary industry from 1984 to 1997, but it drastically decreases from 1997 to 2012. The share of elderly workers in primary industry increased from 1984 to 2012 (Fig. 6). In particular, the proportion of those aged 70 or over exceeds 40% in 2012, compared to around 15% in 1997. From this, it can be considered that the proportion of primary workers over 70 years old increased. These changes could have caused the decrease in working hours and the out-of-home time.

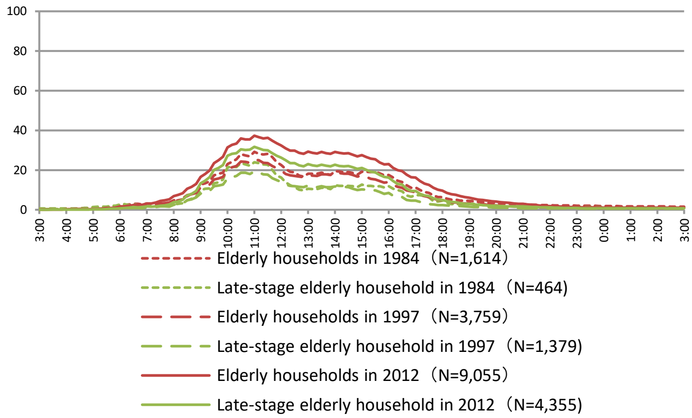


Fig. 8. Change in HEMO rate by the household categories between 1984, 1997, and 2012: the elderly household

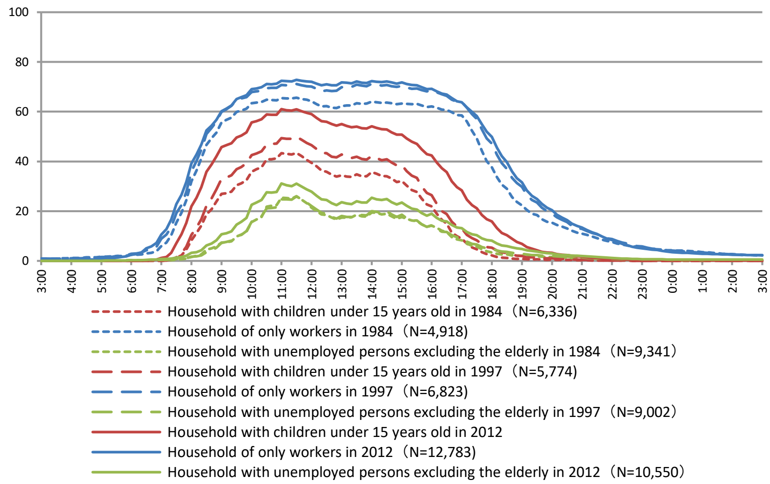


Fig. 9. Change in HEMO rate by the household categories between 1984, 1997, and 2012

3.3. HEMO rate: Household characteristics

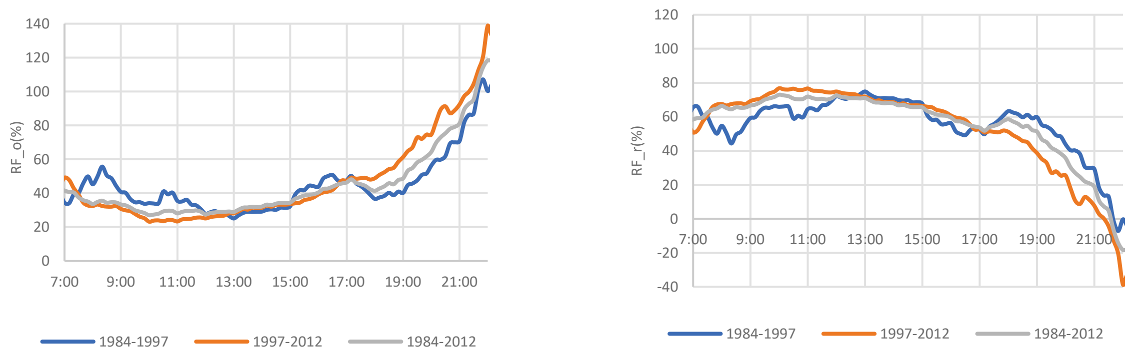
Fig. 7 demonstrates the change in HEMO rate by household size. Large household size produces a high HEMO rate because one in-home person reduces HEMO. Remarkable change is observed in large households. Fig. 8 and Fig. 9 demonstrate the change in HEMO rate by household category. Here, we define the elderly household as a household including only members of 65 years old or older, and the late-stage elderly household as a household including only members of 75 years old or older. Little change is observed in the HEMO rate in elderly households and late-stage elderly households from 1984 to 1997, but a remarkable increase is seen from 1997 to 2012 (Fig. 8). This is caused by the increase in the number of active seniors in these periods as mentioned before. Fig. 9 shows the steady increase in the HEMO rate for households with children under the age of 15 from 1984 to 2012. This may be caused by the increase in the number of working mothers in this period.

Table 2. Change in household composition: classification based on the number of household member

	1984	1997	2012	$\Delta r_i(1997-1984)$	$\Delta r_i(2012-1984)$
1 person	23.6%	28.3%	36.0%	4.7%	12.4%
2 people	27.4%	29.6%	33.0%	2.2%	5.6%
3 people	19.0%	17.5%	16.6%	-1.5%	-2.4%
4 people	18.7%	14.9%	10.4%	-3.8%	-8.3%
5 people	7.4%	6.3%	3.0%	-1.1%	-4.4%
6+ people	4.0%	3.5%	1.0%	-0.5%	-3.0%
Total	100%	100%	100%	0%	0%

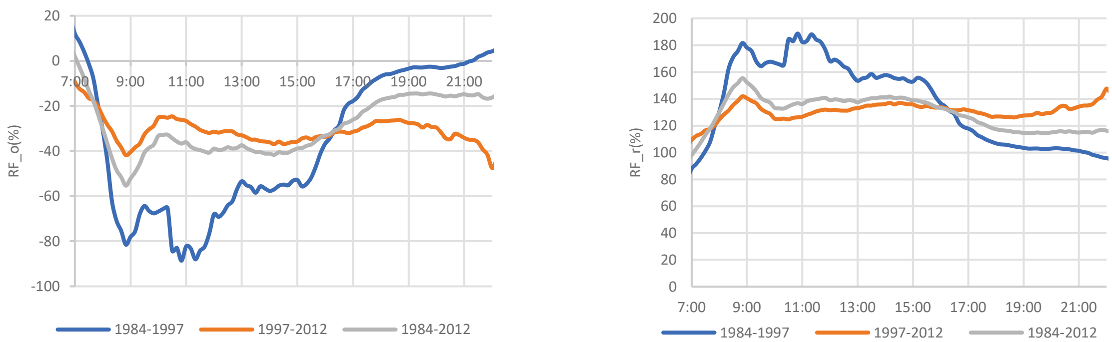
Table 3. Change in household composition: classification based on the ages of household member

	1984	1997	2012	$\Delta r_i(1997-1984)$	$\Delta r_i(2012-1984)$
Household with children under 15 years old	30.1%	22.8%	20.4%	-7.3%	-9.7%
Households with only members between 16 and 65 years old	51.4%	49.5%	43.7%	-1.9%	-7.7%
Households with senior (65+) members only	7.7%	14.8%	23.6%	7.1%	15.9%
Others	10.7%	12.9%	12.3%	2.2%	1.6%
Total	100%	100%	100%	0%	0%



(a) RF_O caused by households-type composition change (b) RF_r caused by the HEMO rate changes by household-type

Fig. 10. Change in the percentage of the factors using classification based on the number of household member.



(a) RF_O caused by households-type composition change (b) RF_r caused by the HEMO rate changes by household-type

Fig. 11. Change in the percentage of the factors using classification based on the ages of household member.

3.4. Factor Decomposition of HEMO Change

Here we decompose the HEMO change between 1984, 1997, and 2012 using the method shown in 2.2. To use the method, we have to define the household-type and several classifications exists to categorize households. This study uses two classification: One is based on the number of household member, and the other is based on the ages of household member. Table 2 and Table 3 demonstrate these two classifications and changes in household composition and HEMO rates for household types.

Fig. 10 demonstrates the change in the percentage of the factors RF_O and RF_r using classification based on the number of household member. Note that the values in early morning and midnight should be ignored because original HEMO rates in these times are quite low and very small change can produce fluctuations. With this in mind, we observe two findings. First, we find that RF_O is small on daytime. In other words, the increase in the HEMO rate during the daytime was largely due to the change in the HEMO rate by household type. Specifically, increasing active seniors would be one main reason of these HEMO increases. Second, RF_O have a sharp increase around 22:00 and it exceed 90%. In other words, the increase in the HEMO rate around 22:00 was caused by change of household composition. Specifically, the increase in single-person households and the decrease in the average number of household-member will cause these changes. These findings illustrate that factors producing HEMO change varies with time of day.

Fig. 11 demonstrates the change in the percentage of the factors RF_O and RF_r using classification based on the ages of household member. We found that RF_O was negative value in most of time (Fig. 11(a)). In other words, the changes in the ages of household member had negative impact on the HEMO rate change. This is because the percentage of elderly households with low HEMO rates had increased and those by active age had decreased (Table 3). Meanwhile, the RF_r demonstrate the value higher than 100% in most of time (Fig. 11(a)). Please note that $RF_O + RF_r = 100$ as shown in eqn. (10). The high value of RF_r is caused by the increase in HEMO rate by household type. For example, the HEMO rates of elderly households and households with children under 15 had risen significantly over the years (Fig. 8 and Fig. 9). These results indicate the HEMO rate changes by household-type outperformed the change caused by household composition change.

4. Conclusion

This study demonstrates a new use of household travel survey data; investigation of households with every member out-of-home (HEMO). Using PT surveys in Kumamoto, Japan, this study compares the individual out-of-home (IO) rate with HEMO rate in three time periods: 1984, 1997, and 2012. The most important finding is that the HEMO rate has increased greatly, while the IO rate change is small.

Future research and analysis include the careful investigation of the factors of HEMO change. Takahashi et al. (2018) proposed a method to decompose the factors of HEMO change and the application of their method on our data is promising. Also, we are now analyzing the household travel survey data in other cities in Japan. The time series intercity comparison of HEMO will give us another insight.

The increase in the HEMO rate has resulted in the increase in redelivery of parcels, which is a major problem in Japan. The results of this research can contribute to solving the redelivery problem. Also, the data can be used for safety research in the housing district for crime prevention, developing an efficient interview-based visiting-survey method, and rough estimation of power in a district.

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