Asian Transportation Research Society

Estimating bus passenger loading in London using Automated Fare Collection system and Automatic Vehicle Location system

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Contents

I. Introduction

"**The passenger load** is simply the number of passengers on a single transit vehicle " (Transport Research Board, 2003).

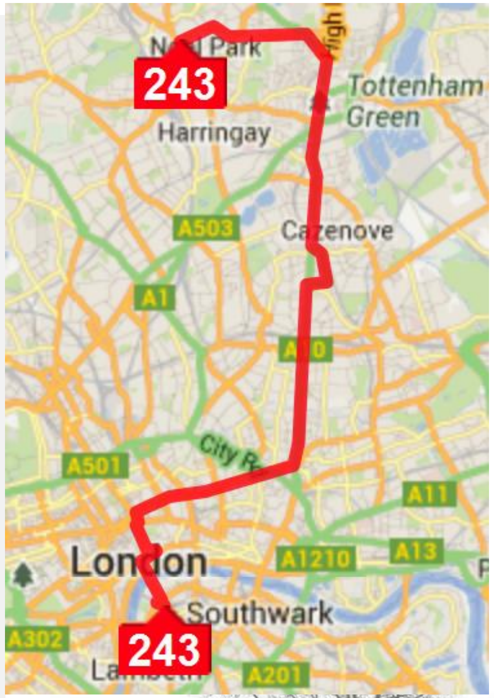
Bus passenger loading is valuable in formation for bus operation planning and bus service management.

Objectives

- Explore possibilities for improving passenger loading estimates using new on-board technologies and new supporting algorithms.
- Evaluate a proposed new methodology and its accuracy using a case study on a bus route in London.

Scope

- Bus route 243 in London from Redvers Road to Waterloo Station/Mepham Street (16.5km long with 59 stops for each direction).
- Oyster card data and iBus data on 10th July, 2013.
- Manual surveys on 10th July, 2013.



II. Data collection

1. Oyster card is a 'contactless' smartcard (Automated Fare Collection system).

Oyster card data: 37, 874 Oyster transactions on bus route 243 of 29,005 Oyster card holders are recorded on 10th July, 2013 (provided by Transport for London).

Table 1: Oyster card data sample

Card number	Transaction time (in minute after midnight)	Sequence number of transaction	Boarding Bus stop ID
1	666	18503	2080
2	764	10091	26425
3	949	111	1116
…	…	…	…
19	368	5995	10948
19	805	5996	318
…	…	…	…

II. Data collection

2. iBus is an integrated Automatic Vehicle Location system.

- Satellite tracking and GPRS data transfer are equipped on all buses in London.
- 322 trips running on 10 July 2013 are recorded, of which 14 trips after midnight 11 July (provided by TfL).

Table 2: iBus data sample

Route	Direction	Bus trip number	Bus stop ID	Stop Name	Stop sequence	Observed Arrival Time	Observed Departure Time
243	1	1	25362	Redvers Road	1	4:02:38	4:02:38
243	1	1	10948	Wood Green Crown Court	2	4:03:20	4:03:29
...	...	...	...	...	...	...	...
243	2	2	BP4258	Waterloo Station / Tenison Way	1	5:05:04	5:05:19
243	2	2	25893	Waterloo Bridge / South Bank	2	5:06:09	5:06:09
...	...	...	...	...	...	...	...

II. Data collection

3. Manual survey

- 4 trips (trip 68, 119, 138 and 191) were observed by 2 surveyors from 8:51 to 15:47 on 10th July, 2013.

- The surveyors boarded a bus at the beginning of the bus route, alighted the bus at the destination of the bus route and observed the following data fields for every bus stop.

Table 3: Manual survey sample

No	Bus stop name	Arrival time	Boardings	Alightings	Departure time
1	Waterloo Station/Tenison Way	8:51:44	73	0	8:55:15
2	Waterloo Bridge/South Bank	8:57:21	0	0	8:57:21
3	Lancaster Place	8:58:43	0	0	8:58:43
4	Aldwych/Drury Lane	9:01:10	2	2	9:01:20
…	…	…	…	…	…

II. Methodology

1. Boarding inference

- Expected value of Oyster transaction time is assumed to be equal to the value recorded in the Oyster database plus 30 seconds.

- Match Oyster transaction times with iBus arrival/departure times to infer boarding bus trip number for each Oyster transaction.

- Using MATLAB (Matrix Laboratory) program to look up bus trip number according to the process (see figure 1).

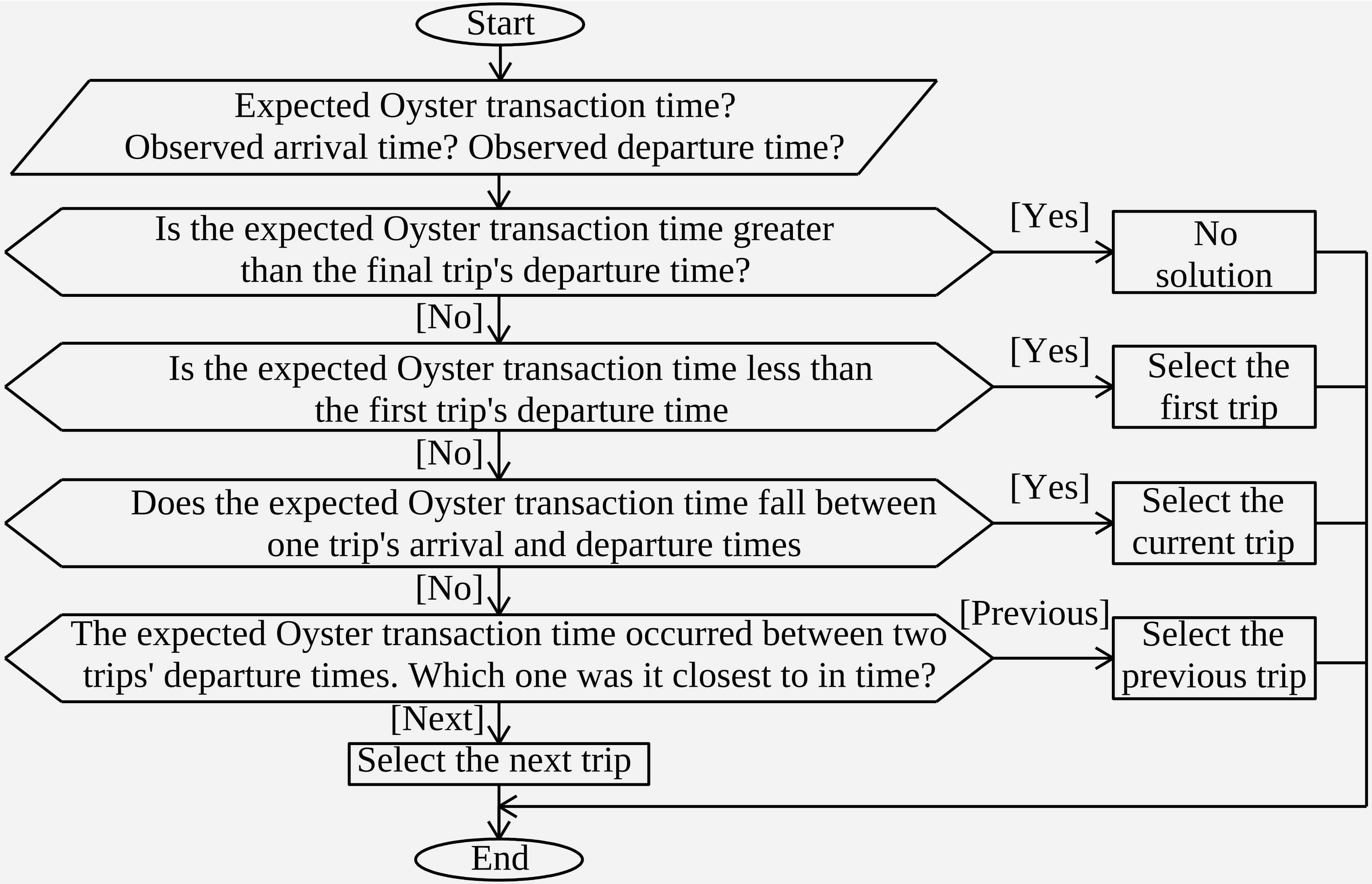


Figure 1: Diagram of boarding inference

II. Methodology

2. Alighting inference

- Each Oyster transaction has ID card, bus trip number, transaction time and boarding stop.
- Assumptions:

(1) Alighting stop of a journey is boarding stop of the next journey.

(2) Alighting stop of the last journey of day is boarding stop of the first journey of day.

- Using MATLAB program to look up alighting bus stops according to the process (see figure 2).

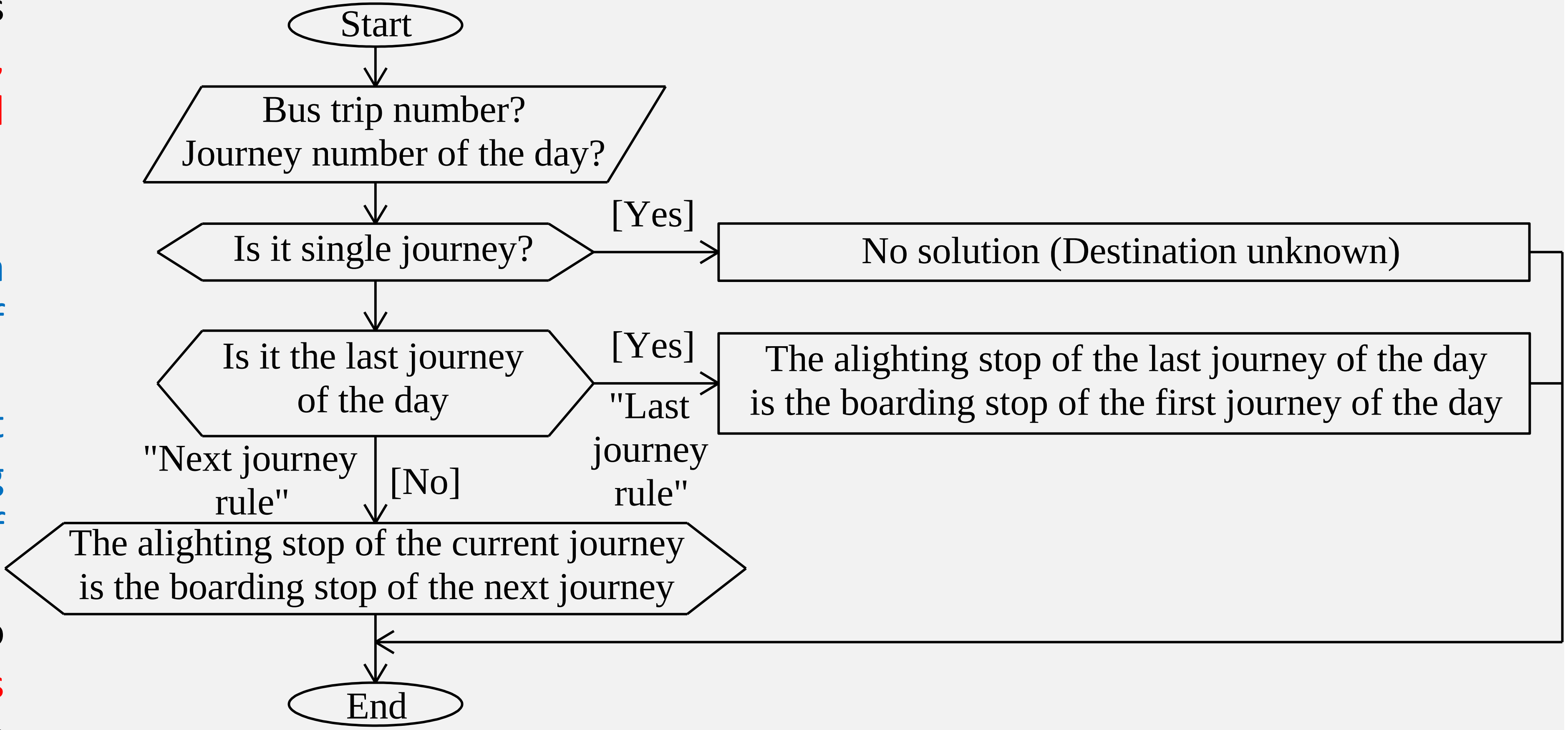


Figure 2: Diagram of alighting inference

II. Methodology

3. Loading estimation

- Inferred boardings and alightings at each bus stop are expanded to ensure that:
  - ✓ Non-Oyster passengers are taken into account (multiplied a factor of 1/94.6%, see Table 4).
  - ✓ Total boardings and alightings for one completed trip are the same.
- For each data of one trip, bus passenger loading at bus stop j is calculated:

$$L_{i,j} = \sum_{k=1}^{j} (B'_{i,k} - A''_{i,k}) \qquad (1)$$

Where:

- ✓ $L_{i,j}$ is the number of loadings for bus trip number i at bus stop number j.
- ✓ $B'_{i,k}$, $A''_{i,k}$ are the number of expanded boardings and expanded alightings for bus trip number i at bus stop number k (k = 1, 2, 3, … j).

III. Results from automated data

1. Boarding inference

- 36,937 (97.5%) of Oyster transactions are inferred to have origins and bus trips.

Table 4: Total inferred boardings for 4 trips 68, 119, 138 and 191

Trip number	Total inferred boardings	Total actual boardings	Inferred Percentage
68	178	184	96.7%
119	120	127	94.5%
138	142	152	93.4%
191	147	157	93.6%
Total	587	620	**94.6%**

2. Alighting inference

- 14,173 of 36,937 transactions (38.4%) have destinations inferred.
- Reasons: 57.9% of transactions were single journey and 3.7% of transactions have invalid inferred results.

3. Loading estimation

- 322 bus trips are scheduled on 10th July, of which 305 have loading estimation.
- The remaining 17 include 14 early trips after midnight 11th July and 3 trips missing iBus data.

IV. Comparison of boarding, alighting and loading between automated data and manual survey data

1. Boarding comparison

- Results for trip 68, 119, 138 and 191 show that inferred boardings at each bus stop can be very close to actual boardings.

- Thus the boarding inference methodology has acceptable accuracy.

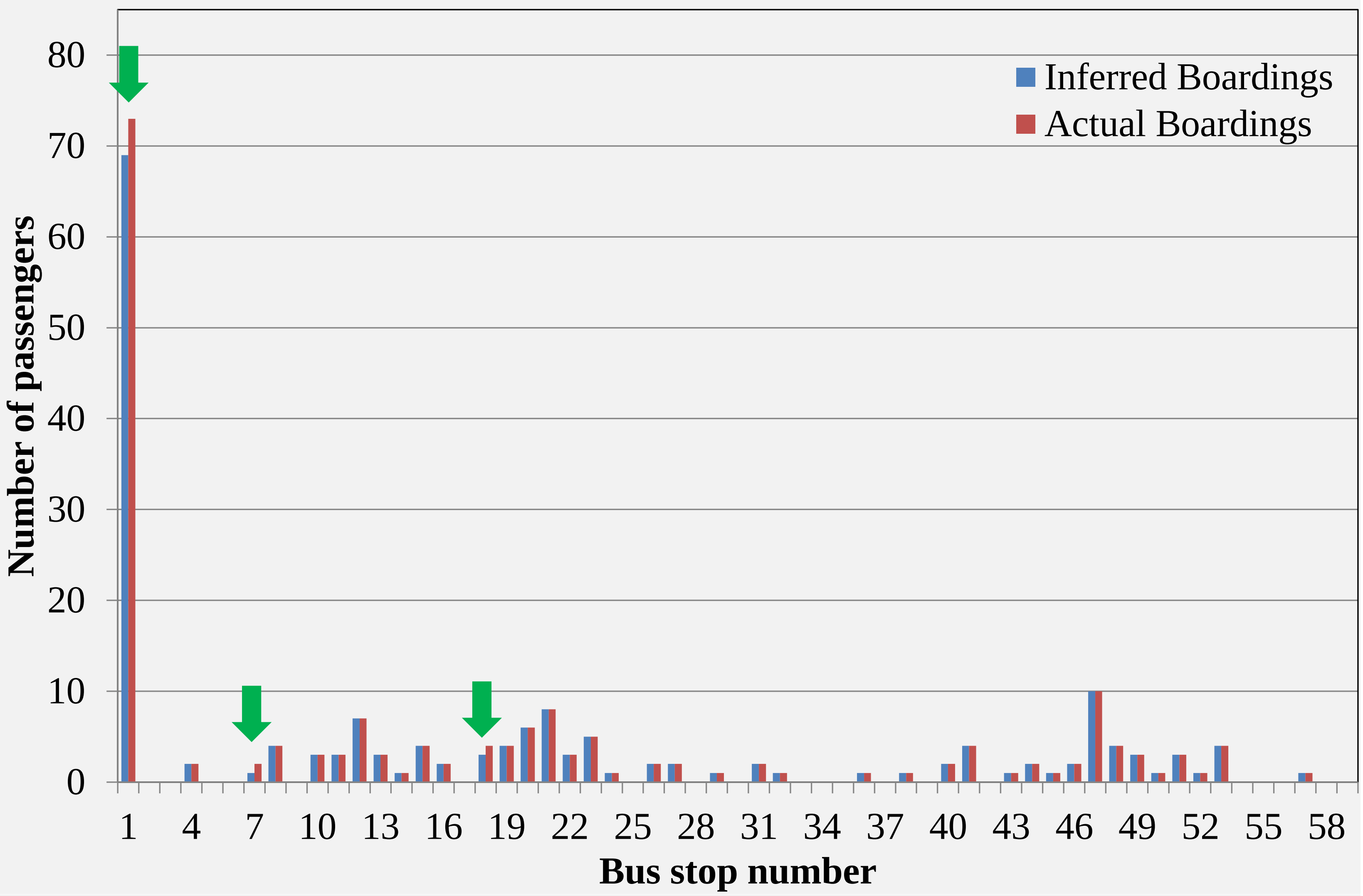


Fig. 3 Boarding comparison for trip 68

IV. Comparison of results between automated data and manual survey data

2. Alighting comparison

- Results suggest that range of alighting difference are mainly from zero to 3 passengers, except few differences of 4 to 6.

- Therefore, the alighting inference methodology might be accurate enough.

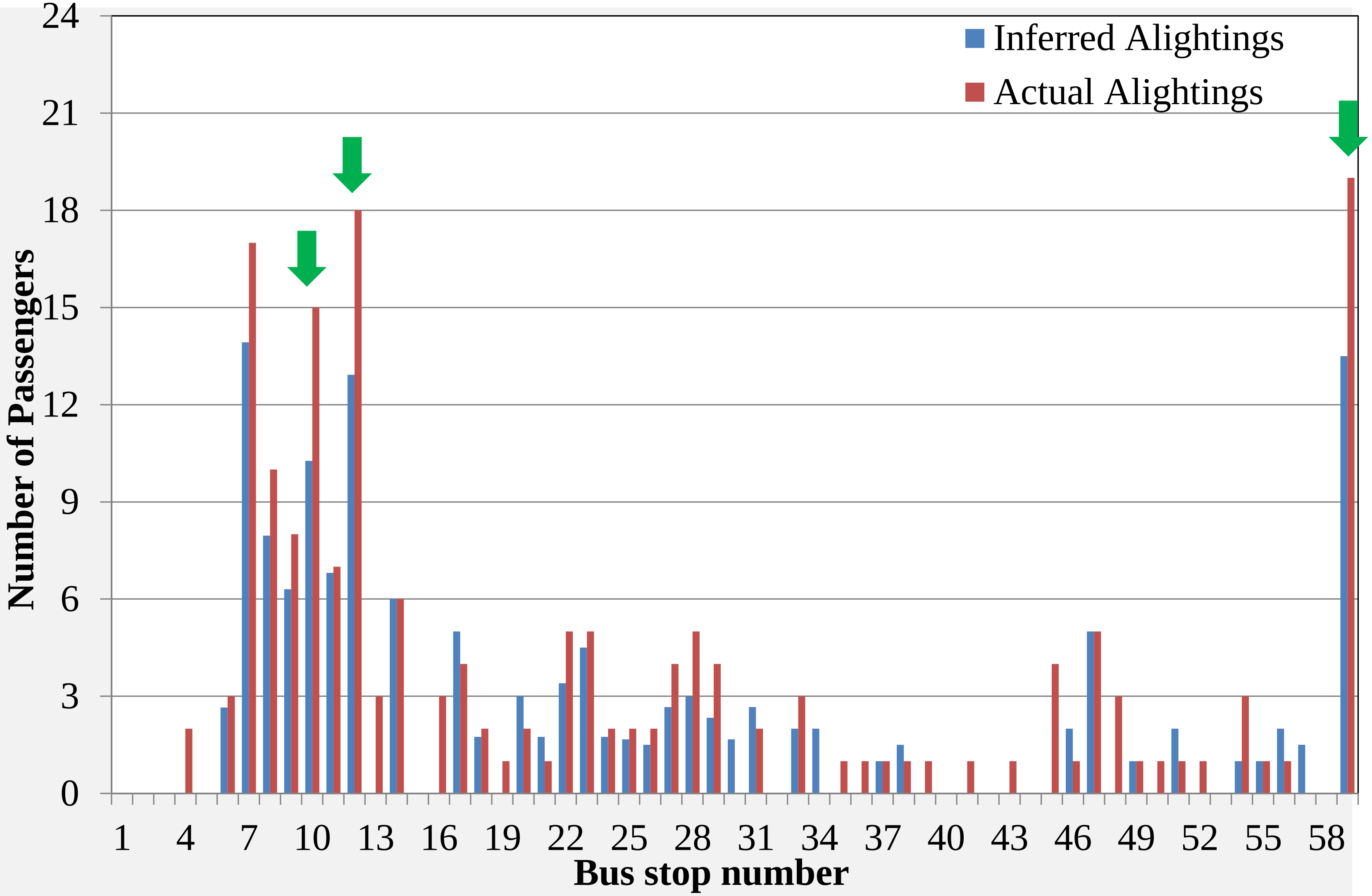


Fig. 4 Alighting comparison for trip 68

IV. Comparison of results between automated data and manual survey data

3. Loading comparison

- Results indicate that estimated loadings and actual loadings are similar along the route, although few large differences in short segments.

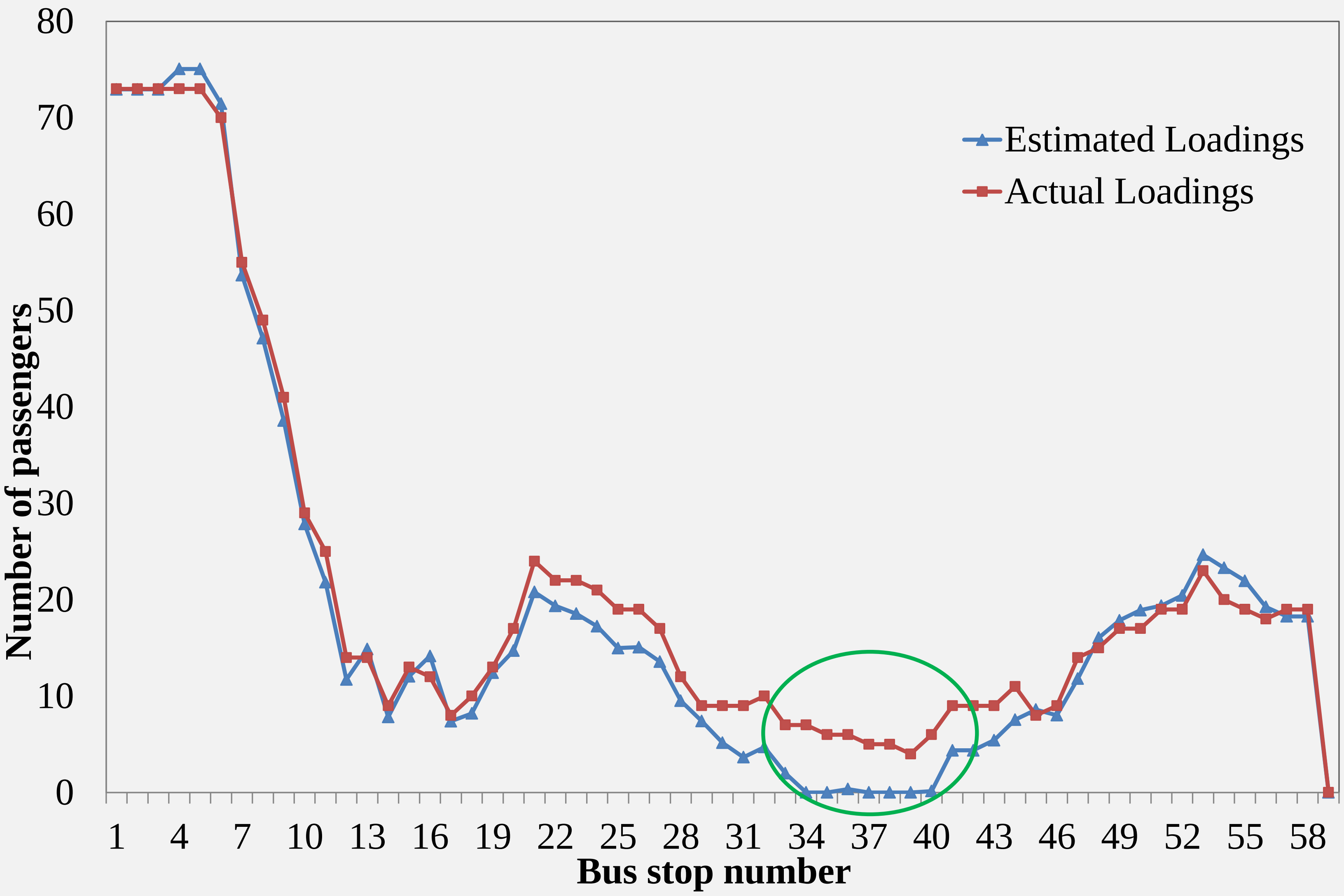


Fig. 5 Loading comparison for trip 68

V. Prediction model of bus passenger loading in real time

1. Prediction model

- The model can be developed by using an algorithm based on average alighting rate and boardings.

- Alighting rate, which is the ratio of alightings to loadings at each bus stop, is identified from historical Oyster data and iBus data. Average alighting rate presents for different time periods of day.

- Loadings at next bus stop can be predicted in real time:

$$FL_{(i+1),j} = FL_{i,j} - AAR_{(i+1),j} \times FL_{i,j} + B^*_{(i+1),j}/0.946 \quad (2)$$

Where:

- $FL_{(i+1),j}$ is number of forecasted loading at bus stop number (i+1) for the trip in period j.
- $FL_{i,j}$ is number of forecasted loading at bus stop number i (previous stop) for the trip in period j.
- $AAR_{(i+1),j}$ is average alighting rate at stop number i for period j, which is estimated from historical data.
- $B^*_{(i+1),j}$ is number of boardings at stop number (i+1) for the trip in real time. The number can be calculated in real time through the ticket machine after Oyster card holders tap their cards on the card reader.
- (1/0.946) is adjusted to take into account of non-Oyster passengers (see Table 4).

V. Prediction model of bus passenger loading in real time

2. Applying the prediction model to three trips 68, 138 and 191

- This model is applied for each direction during different time periods.
- Applying the model to trip 191 (direction 1, Midday); trip 68 (direction 2, AM peak) and trip 138 (direction 2, Midday) to test its accuracy.
- Conclusion: forecasted data are consistent with manual data, though few inconsistencies for short segments.

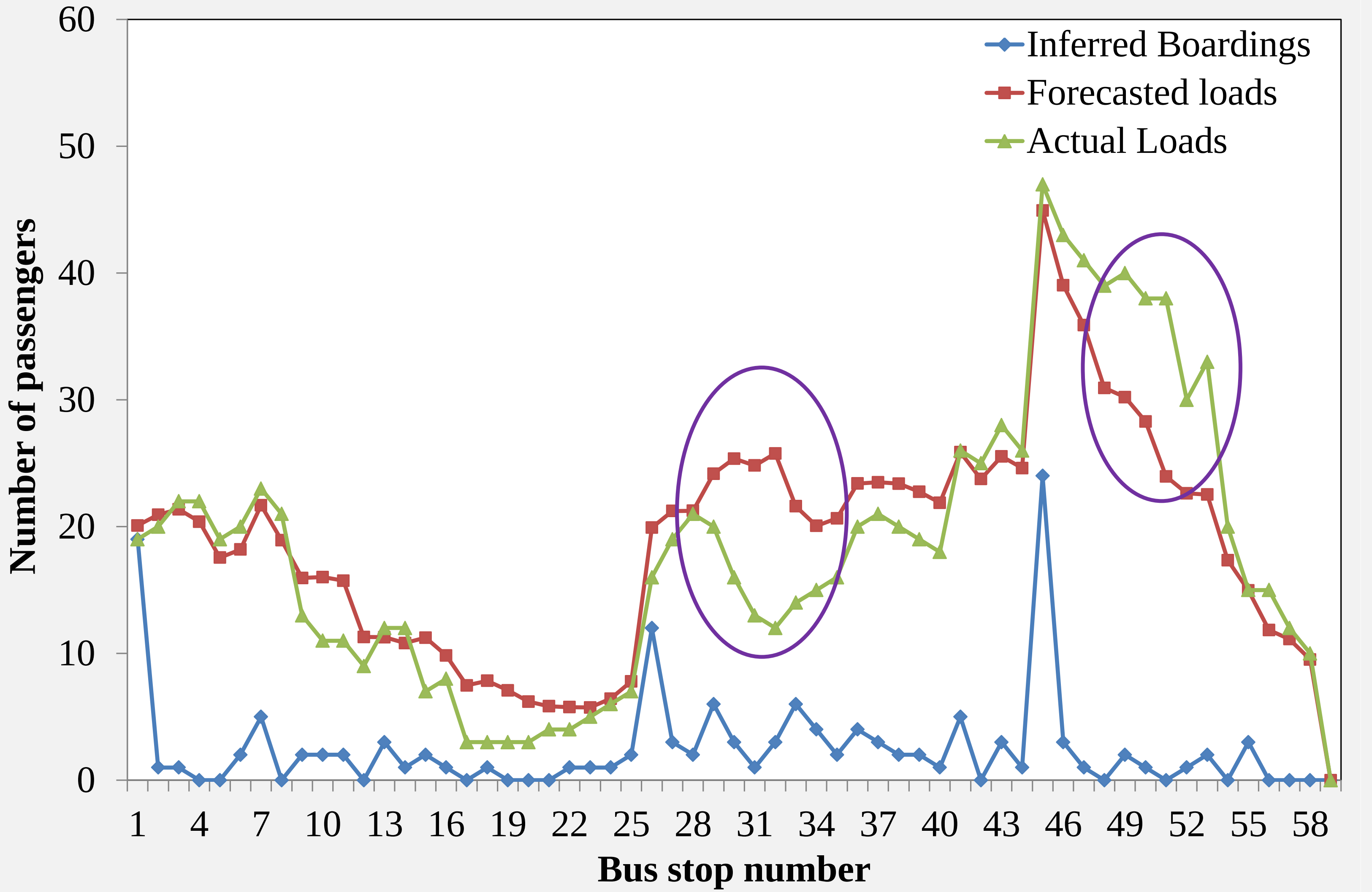


Fig. 6 Comparison between forecasted loads and actual loads for trip 191

V. Prediction model of bus passenger loading in real time

3. Hypothesis testing

- A Paired-Samples T Test is carried out to test that forecasted loads and actual loads of each bus trip are the same at 59 bus stops.

- Let's create a variable $D_i = FL_i - AL_i$ (3)

Where:

- D_i is difference in passengers between forecasted loads and actual loads at bus stop number i.
- FL_i, AL_i are the number of forecasted loads and actual loads at bus stop number i.

- Null Hypothesis is H_0: $\delta = 0$.

- Alternative Hypothesis is H_1: $\delta \neq 0$ (Two sided alternative hypothesis). Sample size: $n = 59$.

- This test is carried out by using SPSS program.

- Results: P value for trip 191 is 0.428 > 0.025 (test point) and the values for trips 68, 138 are 0.000.

- Conclusion: There is no evidence (at the 5% level) to reject the suggestion that forecasted loads and actual loads of bus trip 191 are the same at 59 bus stops. Whilst the suggestions for trip 68 and 138 are rejected.

VI. Conclusion and recommendations

1. Key findings (1)

- The methodology for boarding/alighting inference and loading estimation using AFC/AVL systems has acceptable accuracy.
- This prediction model of loading in real time is suggested as an approximate application rather than an absolute one, and is feasible in reality.
- This study might be helpful for London bus planners to evaluate some bus route standards such as maximum standees, standees versus no-standees and duration of standee time, bus capacity and bus frequency.

VI. Conclusion and recommendations

1. Key findings (2)

- This method of estimating bus passenger loading and this prediction model can be potentially transferred and implemented in other major cities in Europe, the United States and South America, Asia where AFC system and AVL system are being operated in transit agencies.

- Hanoi, the capital of Vietnam, is a feasible case. Smart card system and AVL system have begun to be equipped for only bus route 6 since 2014. After collecting historical smart card data and AVL system data for the route 6, this method might be used feasibly.

2. Recommendations

- More complete and accurate iBus data: a system or supervisors at the bus control centers are necessary to remind drivers to log in/off on the bus iBus system on time at the beginning/end of a completed trip.
- Improve the temporal precision of recorded Oyster transactions, which should be shown in seconds.

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Thank you for listening!

Questions and Answers?