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Travel Wait Time Estimation using Rejsekort Data

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Abstract

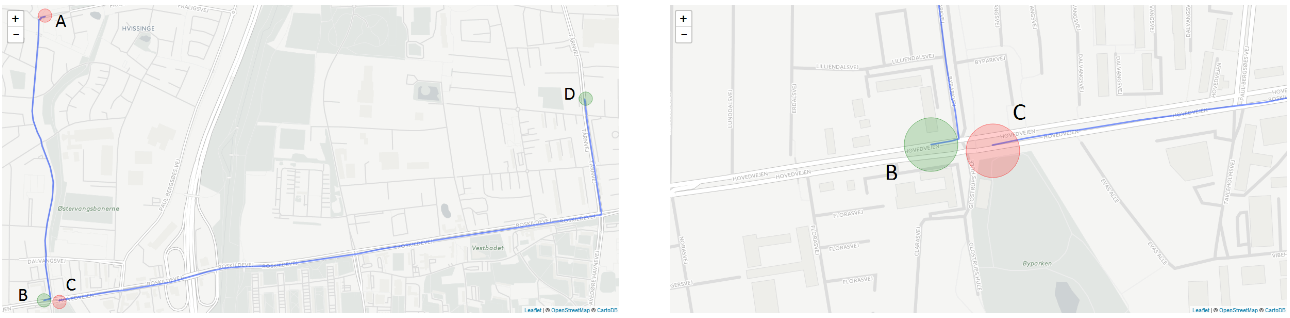
This paper presents a method for estimating passenger wait time at bus terminals and stops during trips with transfers. The method combines data from the danish electronic ticket system, *Rejsekort*, AVL (Automatic Vehicle Location) systems, and topological data of bus routes and walking paths. To demonstrate the method, it is applied to a selected traffic hub and period of interest and results are presented.

1 Background and purpose

Minimizing waiting time at bus terminals and stops are of major impact for achieving an overall efficient point-to-point service for passengers. Research has shown that travel time and service quality are weighted as more important factors, than the monetary fare cost, when choosing between public and automobile transport [2].

Studies reveals that waiting time at stops is perceived as two to three times as onerous as in-vehicle travel time [9], and that the wait time is perceived as much longer than the actual time elapsed [5]. Surveys further show that the effect can be counteracted with bus stop equipment, e.g. benches, shelters, and specifically real-time departure information signs, significantly reducing perceived wait time [3]. Measuring and understanding travel wait time is thus an important step in providing public transport as a competitive and attractive alternative to other modalities. For example identifying insufficient or overly optimistic correspondences, or prioritize stop equipment at bus stops with high wait time.

Figure 1 (a) shows a overview of a passenger trip combined of two bus routes, R_1 an R_2. The red and green circles indicate respectively boarding and alighting during the trip. The transfer between the two routes is showed in close-up in (b).



(a) Overview of trip

(b) Close-up of transfer

Figure 1: Passenger trip with transfer between two bus routes.

The purpose is to estimate the passengers waiting time at *Stop C*. To achieve this, data is combined from three data sources: the danish electronic ticket system, *Rejsekort*; AVL (Automatic Vehicle Location) systems monitoring the bus vehicles; and finally topological data of bus routes and walking paths.

To demonstrate the proposed method, it is applied to data from a selected traffic hub in the Greater Copenhagen Area, and examples of simple analyses based on the method are presented.

2 Method and analysis

The analysis is based on data from the three data sources: the *Rejsekort* ticketing system, AVL systems, and topological data of bus routes and walking paths. Each of the data sources only contributes partly to the overall knowledge of the passenger's movement during the trip. Table 1 summarizes the data available for the example trip (Figure 1) in each of the considered data sources, at different points during the trip.

Point in trip / Data source	Rejsekort	AVL-system	Walking paths
Departure at A (Origin)	Yes, Check In	Yes	No
Arrival at B	No	Yes	No
Walking B to C	No	No	Yes
Departure at C	Yes, Check In	Yes	No
Arrival at D (Destination)	Yes, Check Out	Yes	No

Table 1: Data available at different points of a trip in the systems.

2.1 Data preparation

As seen in Table 1, data from the Rejsekort ticketing system will provide information about the origin and destination of the trip, as well as the boarding onto another route. However the actual bus stop the passenger alighted before the transfer is unknown, as passengers do not check out if their trip continues.

To calculate an estimated travel wait time, it is necessary to estimate the bus stop where the passenger alighted. This is done by firstly matching Rejsekort data with topology data of the specific journey on the route, using the journey identification included in the Rejsekort transactions. This provides the position of each bus stop on the journey, and by combining this with AVL reports using the vehicle identification, also included in the Rejsekort transactions, the actual observed arrival/departure times for each stop on the journey are made available.

Secondly the walking paths for each combination of an alighting/boarding bus stop pair is calculated, where the first argument is a stop point that visited after the boarding stop point of the first journey, and the second argument is simply fixed to the known boarding stop point of the subsequent journey. An alighting bus stop is estimated by minimizing the walking path distance of the pairs.

In other words, it is assumed that the passenger would have alighted at the stop point, serviced by the first bus journey, that is closest to the stop point that was boarded on the subsequent bus journey. This is not an entirely flawless assumption, and will be elaborated further in Section 4.

The result of the data preparation is a transformed dataset on the form shown in Table 2. Both the known boarding times, t_{board}, and the estimated alighting time, $\widehat{t_{\text{alight}}}$, are available from the matched AVL-data monitoring the vehicle. Furthermore the distance of the chosen walking path pair, $w_{\text{from}\to\text{to}}$, is attached to the resulting dataset.

Transfer From			Transfer To			Walking Path
Route	Stop Point	Time	Route	Stop Point	Time	Distance
			R_1	A	$t_{\text{board, A}}$	
R_1	B	$\widehat{t_{\text{alight, B}}}$	R_2	C	$t_{\text{board, C}}$	$w_{\text{B}\to\text{C}}$
R_2	D	$t_{\text{alight, D}}$				

Table 2: Transformed dataset used for analysis.

2.2 Data analysis

The walking time, $\widehat{t_{\text{walk}}}$, is estimated from the walking path distance, with an assumed average walking speed, v, i.e. $\widehat{t_{\text{walk}}} = \frac{w_{\text{from}\to\text{to}}}{v}$. The average walking speed is thus a parameter for the analysis, and has been chosen pessimistically based on [1] to $v = 4.55\frac{\text{km}}{\text{h}}$.

Based on the prepared dataset from Section 2.1, and the estimated walking time, $\widehat{t_{\text{walk}}}$, the travel wait time is estimated cf. (1). Notice that a negative travel wait time is not possible, in such cases the estimate is set to zero, as it is assumed that the pessimistic walking time was overestimated.

$$\widehat{t_{\text{wait}}} = \max\left(t_{\text{board}} - \widehat{t_{\text{alight}}} - \widehat{t_{\text{walk}}},\ 0\right) \tag{1}$$

By applying the above calculation to the prepared dataset the result of the presented method is complete cf. Table 3.

Transfer From			Transfer To			Walking path	Travel Wait
Route	Stop Point	Time	Route	Stop Point	Time	Distance	Time
			R_1	A	$t_{\text{board, A}}$		
R_1	B	$\widehat{t_{\text{alight, B}}}$	R_2	C	$t_{\text{board, C}}$	$w_{\text{B}\to\text{C}}$	$\widehat{t_{\text{wait}}}$
R_2	D	$t_{\text{alight, D}}$					

Table 3: Resulting dataset of the presented method.

3 Results

To demonstrate the proposed method, it has been applied to data from a selected traffic hub in the Greater Copenhagen Area, specifically *Husum Torv*. The sample data covers the period of January 2016 and includes $N = 12\,572$ observations.

The presented method, including data transformations needed for the data preparation, has been implemented using the *R programming language* [7, 6] and walking path distances was calculated using Google Maps Distance Matrix API [4, 8].

3.1 Use case: Time of day

Figure 2 shows the estimated mean wait time during the time of day (blue), including a 95% confidence interval (gray). The lowest wait time is experienced just after the morning peak hours (7-9), and in the end of the afternoon peak hours (15-18). Interestingly it shows that the estimated mean wait time is approximately one minute longer in the afternoon peak (15) than in the morning peak (8).

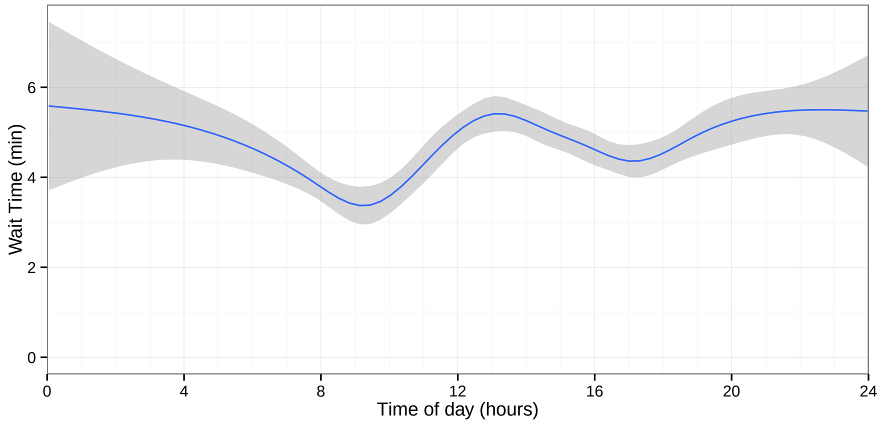


Figure 2: Estimated Travel Wait Time over the day for transfers through Husum Torv.

3.2 Use case: Route combination

Figure 3 shows the estimated mean wait time for the combinations of transfers from and to a route. This highlight that the longest wait time is experienced for passengers that transfers from route 5A to 132.

4 Conclusion

The presented method for travel wait time estimation has been explained and demonstrated on a set of sample data. Unfortunately it has not been possible to measure the accuracy of the method, since actual observations of travel wait time is very sparse. However, since it is based on a sound approach, it is still argued that the method can yield reliable estimations.

The most significant uncertainties is the estimation of the alighting bus stop point, and the assumption of constant walking speed. Especially if other events than walking and waiting occur frequently during a transfer, the method might yield imprecise travel wait time estimations. E.g. at stop points near a shopping mall, it is likely that passengers might alight, shop and board all on the same passenger trip.

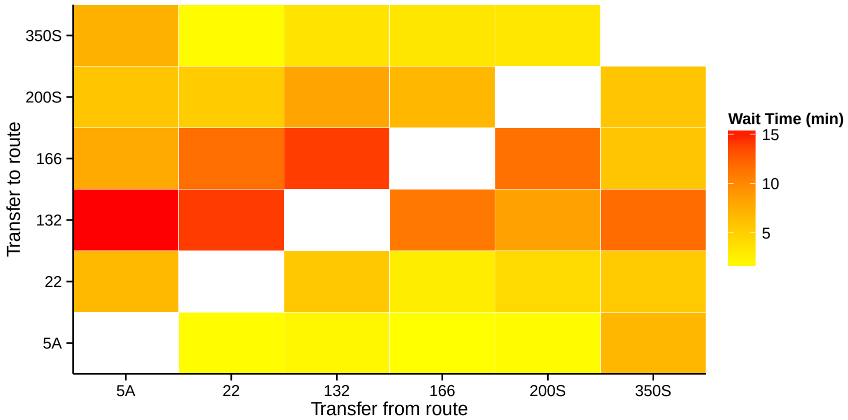


Figure 3: Estimated Travel Wait Time for transfers between route combinations through Husum Torv.

The demonstration shows only the method for a single geographical area, but it will be most interesting to apply the method to different areas for comparative analyses.

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