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Waiting Time Strategy for Public Transport Passengers

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To overcome future challenges in urban transport it is crucial that the transport models provide a better approximation of the real travel costs for public transport trips. Todays transport models use the assumption of random passenger arrivals, which we have proved overestimates the real travel costs passengers is experiencing in low-frequency services. This study presents results from field registrations and surveys, passengers' actual waiting time and their waiting time strategies. The results show that passengers plan their arrival to bus stops, which implies a lower waiting time than assumed in the transport models. Though random arrivals probably represents a realistic arrival pattern in frequent public transport services, the arrival pattern is quite different in low-frequency services. This could partly be defended by saying we include the hidden as well as the registered waiting time. However, it seems unlikely that the current assumptions in transport model is representing waiting time strategy in a meaningful way, and thus it should be investigated further. Results given in this paper indicate how transport models could develop to better deal with low-frequency public transport services.

1 Introduction

Large population growth in cities and environmental concerns across the world puts increasingly higher demands on public passenger transports. In several European cities, including the nine largest urban areas in Norway (Samferdselsdepartementet, 2012), the number of public transport trips is required to increase, with the overall goal of reducing the number of car trips. To overcome the challenges it is crucial that the transport models provide a realistic approximation of the real travel costs for public transport trips. In low-frequency public transport services, which occurs in most Norwegian cities, we expect that the waiting time used in the transport models is much higher than what the passengers choose in real life.

In order to provide reliable estimates of travel demand the transport models' input data must be of high quality. The demand calculations are based on the inconvenience of travels between A and B with every available means of transport. The inconveniences are converted to a common cost unit, and the sum is known as the generalized travel cost (GC). The calculated GC for a trip by public transport consists of the inconveniences of walking to, between and from bus stops, representing the access and egress time, time aboard the vehicle, waiting time, and fares (Malmin, 2013).

Input data used in the transport models regarding the duration of each stage of the trip, with the exception of the first waiting time, probably gives a good representation of the real travel time. The input data for the waiting time that occurs in the start of the trip, before boarding on any vehicle, is not based on any form of registrations of actual waiting times (Hjorthol et al., 2014). It is solely based on time between bus departures (headways). In addition, the modeled waiting time is based on an assumption of random passenger arrivals to the bus stops (Amin-Naseri and Baradaran, 2015). With this assumption, the average waiting time for all passengers is the statistical expected value, equal to half the time between departures ($W=h/2$). This might be a good estimation of waiting time in high-frequency services. However, if the passengers plan their arrival to the bus stop, the open waiting time (the duration of passengers' stay on the bus stop) is probably considerably less than half the time between departures in low-frequency services.

It is true that passengers travelling at larger headways might experience hidden waiting time in addition to the open waiting time because they are not able to travel whenever they want. However, the hidden waiting time, as well as extra waiting time due to bus delays, does probably not have the same time costs as the open waiting time, and the differences is not taken into account in today's implementations.

Based on field studies carried out in Trondheim, Norway, we have investigated the waiting time among public transport passengers. A survey followed up results from the passenger arrival registrations, to get more information on how passengers plan their waiting time. Together, this data has given us more insight into public transport passengers waiting time strategy. Based on this new knowledge, we have taken one step closer to better approximations of reality in the transport models.

2 Method

2.1 Study design

In this study, we wanted to reveal passengers' actual waiting time in low-frequency public transport services. The transport models use the assumption of uniform and random passenger arrivals at all public transport trips, even though this is found to be valid only in high-frequency services (Seddon and Day, 1974, found in McLeod, 2007). This probably results in overestimation of the waiting time in low-frequency services, which is present in most Norwegian cities. The goal of this study is to map actual waiting times for public transport passengers travelling at different headways, and to reveal if there is any correlation between different aspects of the waiting time strategy and the public transport service.

We used two types of data collections. In the first part, the open waiting time of 1145 passengers were registered during the morning peak-hour traffic, in February 2016. The registrations were conducted at 24 different bus stops in residential areas in Trondheim, on 16 different days, and each registration lasted for about two hours. The number of bus routs registered was seven, where two of them were registered at both sides of the city center, and one was registered at two different headways. The passengers were registered with the exact time of arrival to the bus stop. The observed open waiting time is the time between arrival of each passenger and the departure time of the bus they boarded. All bus routes operated according to a timetable with fixed departure times.

In the second part, 109 public transport passengers answered a survey about their waiting time strategy, while waiting at the bus stops.

2.2 Preliminaries and decisions

The entire study aims solely at the first waiting time that passengers are experiencing (waiting time that occurs in the start of the trip, before boarding on any vehicle), and for trips that is presumably starting at home. This is based on the assumptions of 1) that passengers have greater possibilities to plan their arrival to the bus stop when the trip is starting at home, and 2) that waiting times at the trip origin has a higher influence on the mode choice, than at the destination, when the trip purpose is a return journey.

We believe that the arrival distribution of passengers to bus stops will vary with different headways. To investigate this, we decided to conduct registrations on bus stops served by one single bus route, with 10, 15, and 20-minute headways. 10 minutes is the lowest headway existing on bus routs in Trondheim, therefore no registrations on more frequent routes were conducted. 15- and 20-minute headways were chosen because those headways frequently occur on bus routs in Norwegian, and other medium sized cities worldwide. Headways larger than 20 minutes were not investigated because of the difficulties it would cause to collect a sufficient amount of data. Registrations on bus stops that is served by two or more routes were also omitted because of the complexity it would be to collect the data (have to track which bus each passenger is entering).

We conducted registrations manually in the morning peak-hour traffic for 10- and 15-minute headways, and later in the day for 20 minutes headway, as no routes in Trondheim operates with 20-minute headway during the morning peak hours. Only one registration was conducted per site and time period, so that the probability of register the same person more than once was kept to a minimum.

The survey's goal was to clarify what strategies the passengers apply, conscious, or unconscious, when it comes to waiting time at public transport trips. What thoughts, and what considerations that is the foundation of the waiting time that individuals choose, is of great interest. The survey was conducted mostly during the morning peak hours in order to get as many respondents as possible. In addition, these data will be suitable to detect relations between results from the registrations because they were conducted at the same time of day. By only asking passengers at those times, there might be an excess weight of trips to and from work and school. However, the passenger numbers are highest during the peak-hours, and if any information gathered from the survey may be used to improvements in the public transport services, it is during the peak-hours the improvements will have greatest importance.

The challenge was to keep the questions simple, in such a way that the respondents were able to understand the questions, and still get sufficient information about the passengers' waiting time strategy. Therefore, most of the questions were multiple choice. In addition, the number of questions were kept low, in order to maintain the respondent interests for giving accurate answers through the entire survey.

2.3 Arrival registrations

All passengers who arrived the given bus stop were registered with the exact time of arrival, and the same were done for the buses' departure. The definition of when a passenger has arrived the bus stop is not unambiguous. In this study the arrival was defined by the point in time where the passenger stopped walking – and started waiting – independent of the position where this took place. All registrations started and ended with a bus departure, to avoid an over-representation of passengers arriving early and late. The registrations were conducted by using a self-designed application for Android phones and tablet computers, where the time stamp for all passengers and buses were saved to a file.

When processing the collected data, the duration of each individual open waiting time was revealed, by calculating the time between time of arrival and the bus's departure time. When information from the timetable were included, the data also showed on what time the passengers arrived prior to the planned bus departure time, plus delays for every vehicle.

Bus stop characteristics

It is important that the registrations be performed at bus stops that are similar to each other. When the different bus stops have the same characteristics when it comes to location and public transport service, all the collected data will have the same validity. The bus stops we used for registrations satisfy all of the following requirements:

1. It is served by one bus route only.
2. The bus route has a fixed number of minutes between all departures in the registration period.
3. It is located in a residential area.
4. It is not suited for transfers between public transport routes.
5. It is not in close distance of a groceries store, shopping mall, or kindergarten.

These requirements is determined to maximize the probability that it is the passengers' first waiting time that is registered (they have not done any errand in advance), and that they started their trip at home. Additionally, there should not be any other bus stop, served by other bus routes, in close distance. This is to ensure that the travelers actually did plan to go to this particular stop, instead of others.

2.4 Survey design and collecting responses

The survey was aimed at frequent public transport passengers, and gathered information only from the trip each passenger do most frequently by public transport. Only asking questions about one particular trip was chosen because it might cause the passengers to give answers that are more exact, regarding waiting- and excess time. The survey begins with general questions about the passenger and the bus services used for this particular trip, in order to find any correlations between this and the passengers' waiting time strategy. In order to keep the questions simple, no questions regarding time costs were asked. However, different valuing of the different phases of waiting time is of great interest, hence, the respondents were given a scenario where they choose which part of the journey they would like to shorten and increase with one minute.

The survey is internet-based, and the respondents should be able to answer by themselves, using their own cell phone. The main reason for this is to let the passengers conduct the survey while they are either waiting at the bus stop, or are aboard the bus – places they usually do not have much else to do. This will likely results in more respondents. Internet-based surveys might also exclude some potential respondents. However, the use of internet on cell phones at public places in Norway is large; therefore, the number of excluded passengers for this reason was expected to be small.

We collected responses at different bus stops in Trondheim, mostly during the morning peak-hour traffic. The bus stops were selected based on high passenger numbers, in order to get as many respondents as possible in short time. However, this might result in that passengers travelling at times with larger headways is under-represented.

The intention was to ask all the passengers arriving, however, this was not possible. Some passengers arrived just in time before the bus departures, and there was no time to ask them. Hence, it might be an under-representation of passengers who aims for zero open waiting time. Other situations like crowding, and passengers who did not want to answer the survey, resulted in a response rate of around 40%.

3 Results

3.1 Open waiting time

One of the main goals is to map the duration of passengers' open waiting time, which in this study, is the length of passengers' stay on the bus stop, from when they arrive at the platform until the bus departures. Knowing the exact duration of the open waiting time is a considerable contribution in producing better approximation of the real travel costs for public transport trips. Seeing how the arrival distribution varies with different headways, enables the models to calculate more accurate travel costs for travels at any public transport services.

The arrival distributions found at the three different headways is shown as cumulative distribution functions, with the open waiting time along the x-axis, in Figure 1, Figure 2, and Figure 3. Table 1 summarize the differences in open waiting time at the different headways.

Table 1: The observed open waiting time at different headways. All numbers in [mm:ss].

Headway	N	Average open waiting time	Median	Standard deviation
10 minutes	494	03:12	02:39	02:26
15 minutes	457	04:25	03:33	03:07
20 minutes	194	05:33	04:23	04:28

Figure 1: Cumulative arrival distribution at 10-minute headways.

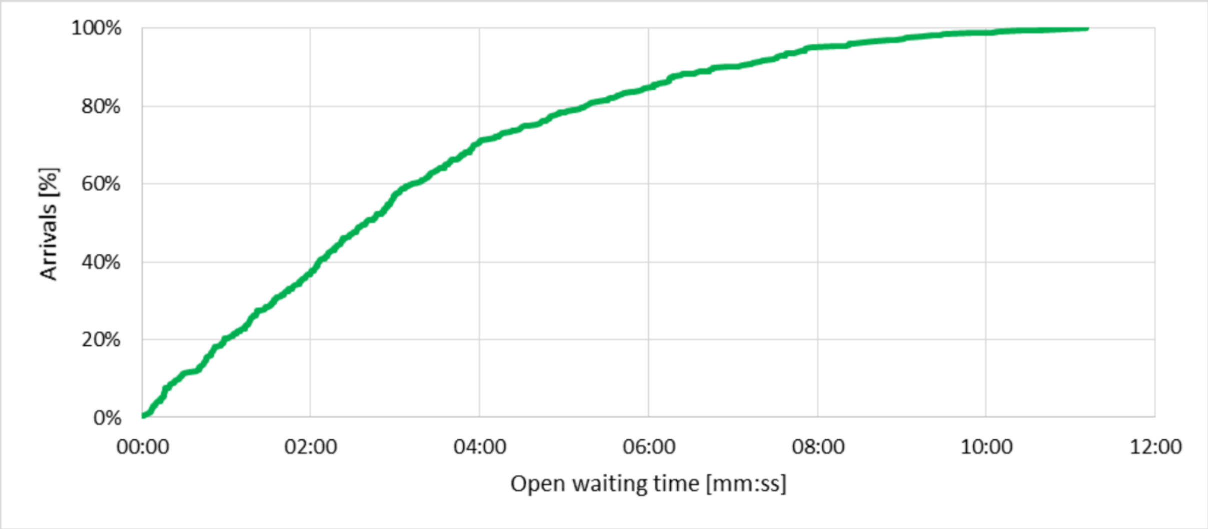


Figure 2: Cumulative arrival distribution at 15-minute headways.

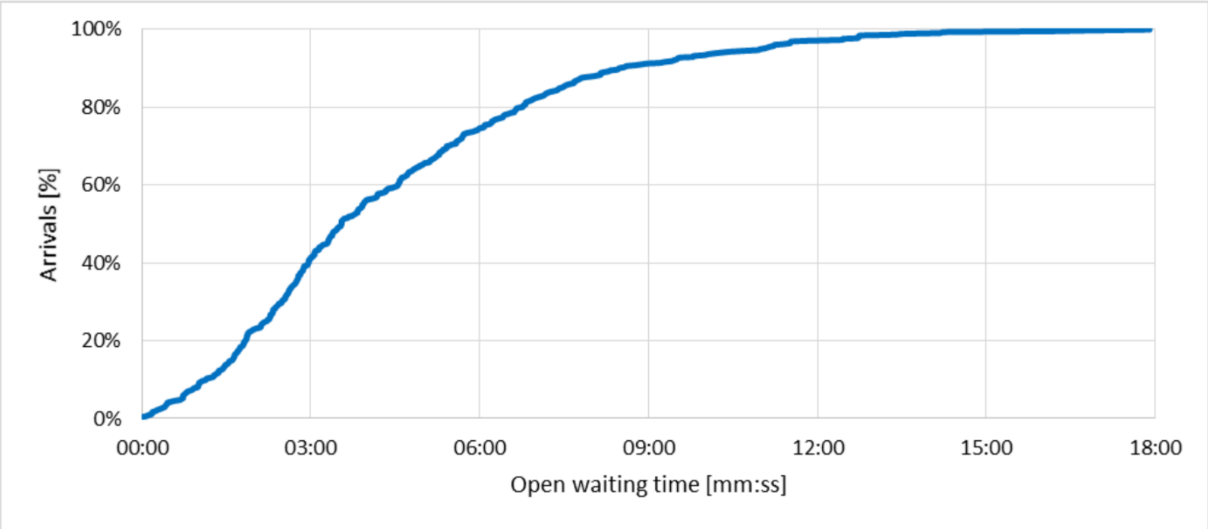


Figure 3: Cumulative arrival distribution at 20-minute headways.

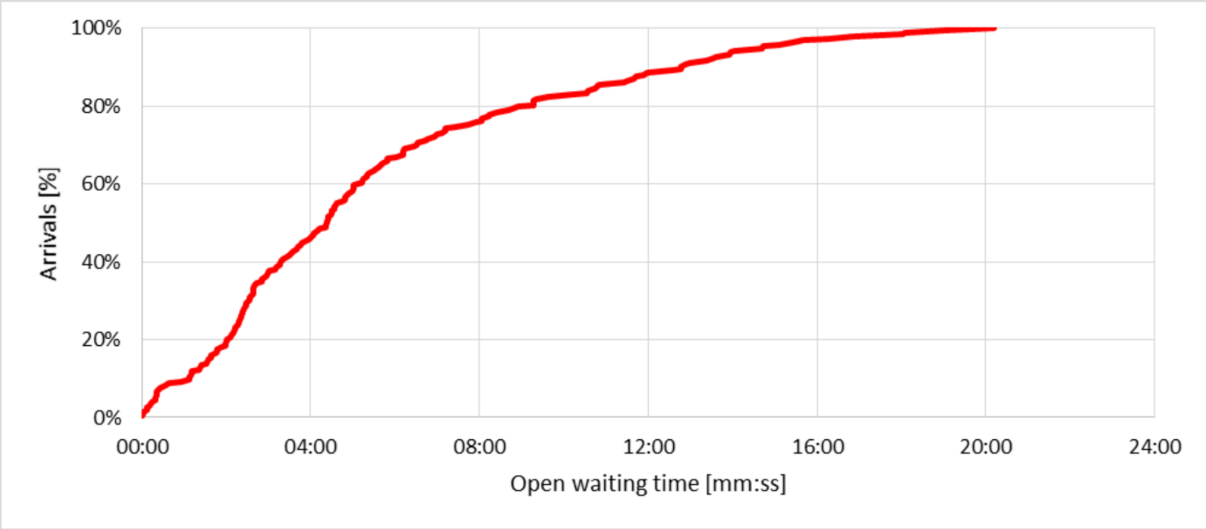


Figure 4: Cumulative arrival distribution at 10-, 15-, and 20-minute headways.

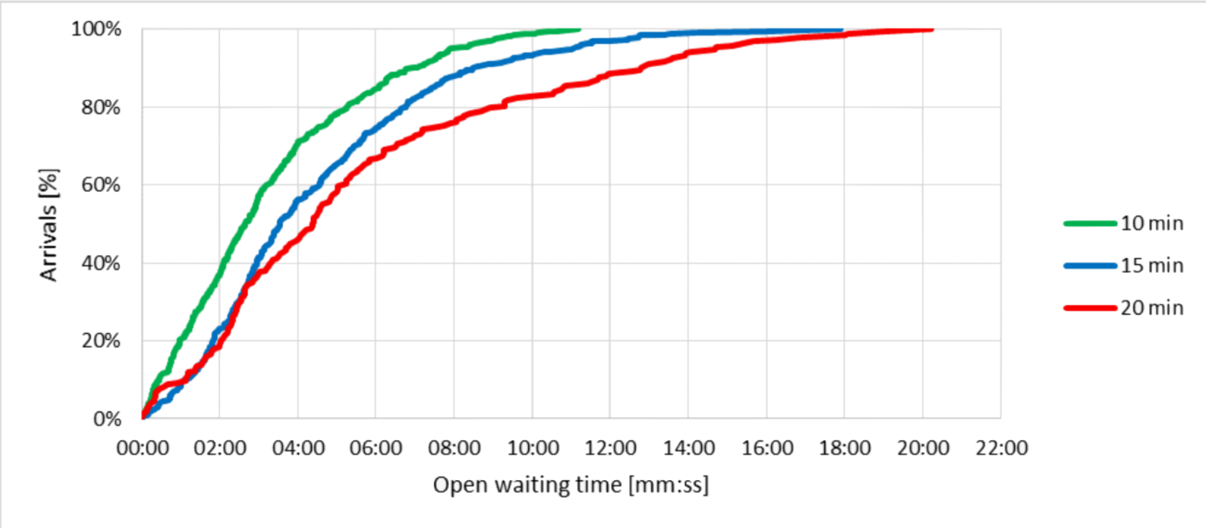
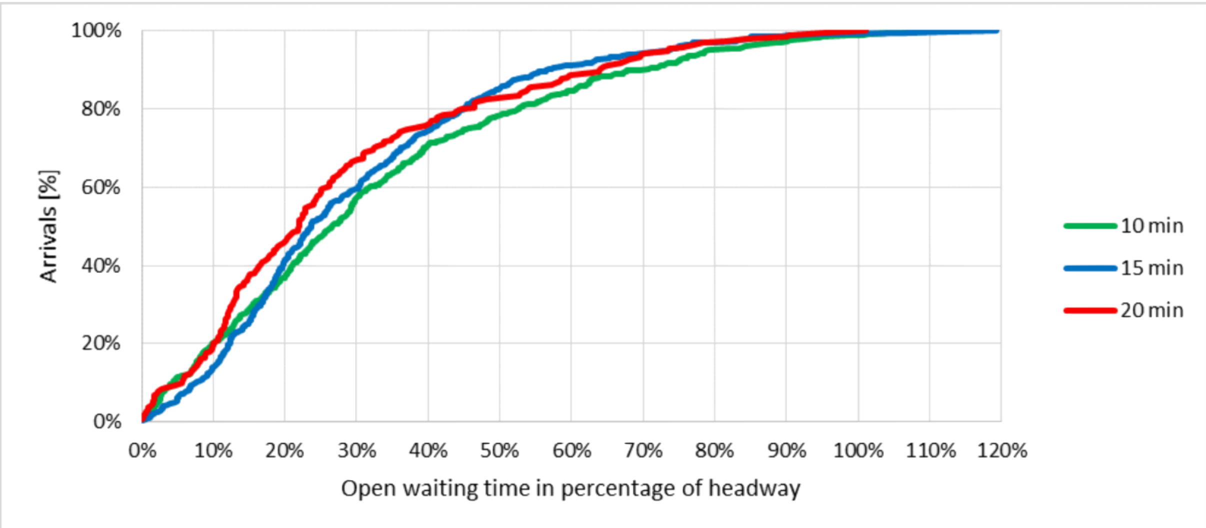


Figure 5: Cumulative arrival distribution at 10-, 15-, and 20-minute headway. Where the open waiting time is given in percentage of the headway.



The results clearly show that the arrival distribution of public transport passengers is not uniform, like it is assumed when waiting time is dealt with in transport models. The distribution shows that passengers tend to plan their arrival to the bus stop according to the bus departure times, in order to reduce their open waiting time. Moreover, this indicates that the waiting time used in transport models in low-frequency services might be overestimated.

The arrival distributions for the three different headways show that more passengers experience longer waiting time at larger headways. This might be a consequence of that passengers travelling with larger headways are taking smaller risks, in form of longer waiting time, to decrease the probability of not reaching their bus. The cost of waiting for the next bus (which will arrive in h minutes) will of course be higher for passengers that are travelling with larger headways. Hence, a lower share of random arrivals is expected at larger headways.

3.2 Is the time of arrival planned?

Knowing how the time of arrival is planned will give crucial information about passengers' waiting time strategy. By analyzing each arrival, and calculate both the arrival time prior to the bus's departure (the open waiting time), and the arrival time prior to the bus's scheduled departure time, such information is gained. By knowing the length of these times, we are able to predict if the passengers did plan their arrival based on the timetable, or by the use of real time travel information. This is because passengers who arrive solely based on information from the timetables will not be able to adapt their arrival in accordance with delays in order to avoid excess waiting time. We cannot say for sure (from these data) what basis every passenger's time of arrival is based on, mainly because passengers also can arrive randomly. However, these results could be used to estimate the share of passengers who arrived on what bases.

The figures (Figure 6, Figure 7, and Figure 8) show a two dimensional diagram, where each dot represents one passenger's arrival to the bus stop. The arrival is plotted with an x-coordinate showing the open waiting time, and the y-coordinate showing the length of time between the arrival and the time for the next scheduled bus departure.

Figure 6: Arrivals at 10-minute headways. Time ahead of actual and planned bus departure.

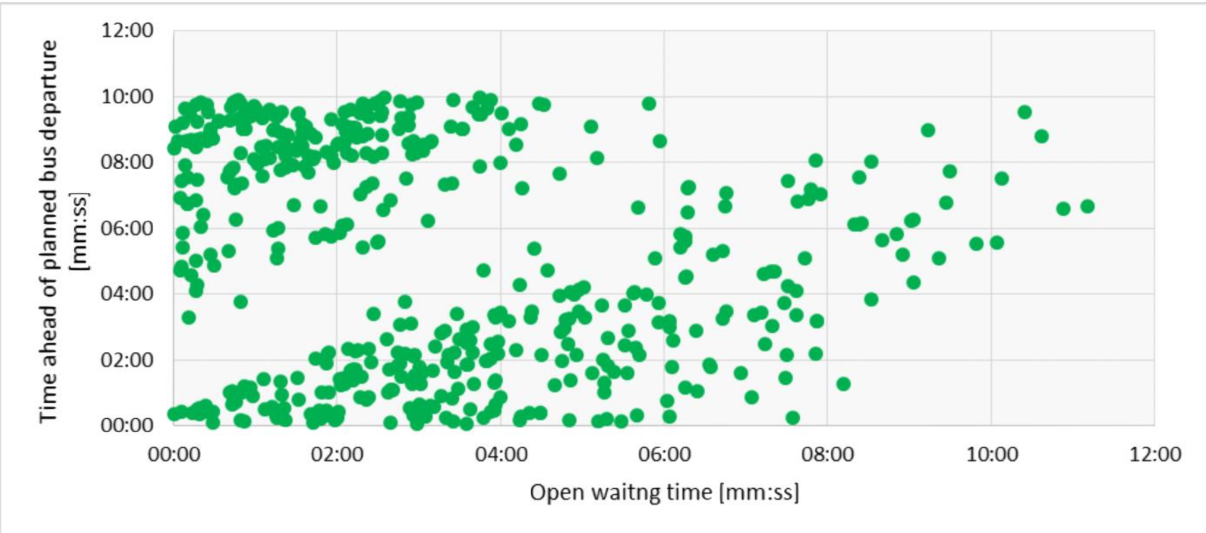


Figure 7: Arrivals at 15-minute headways. Time ahead of actual and planned bus departure.

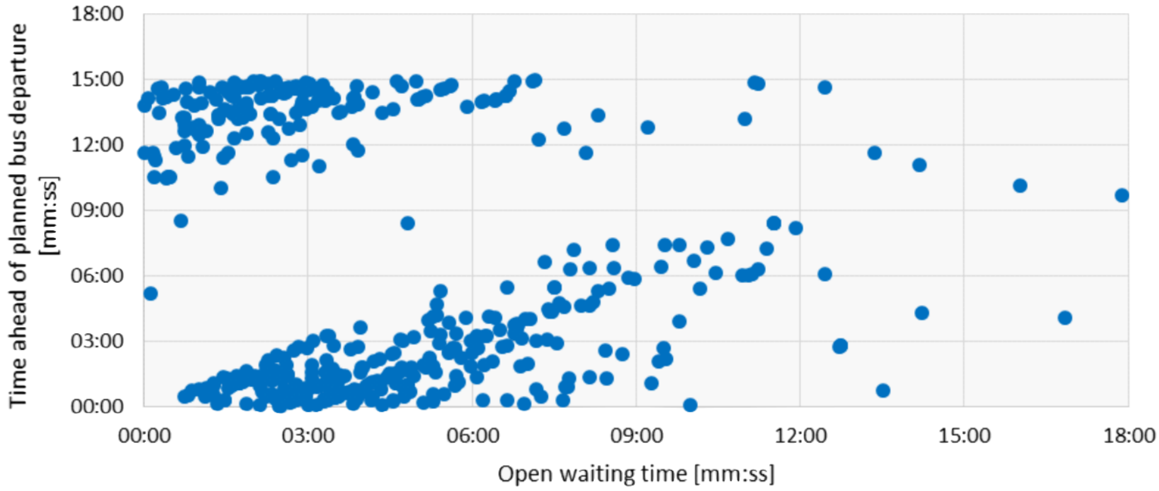
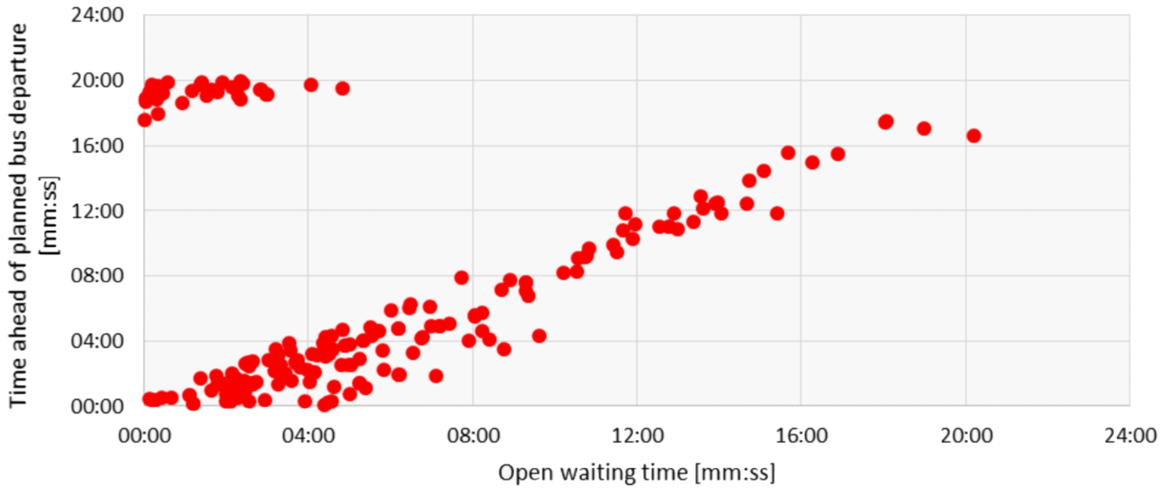


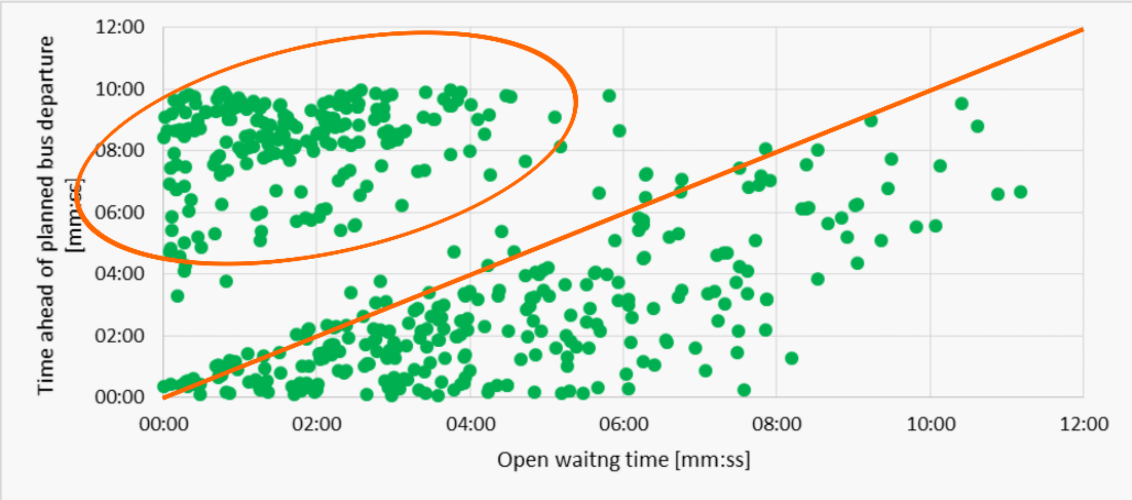
Figure 8: Arrivals at 20-minute headways. Time ahead of actual and planned bus departure.



The diagrams reveal that a share of the passengers experiences a shorter waiting time than expected if we assume that every bus departure on scheduled time. These passengers arrive at the platform after the scheduled departure time, but they still reach the bus, because of delays. In the diagrams they are recognized by that their open waiting time is less than the time before the next scheduled departure, and they are seen in the upper left corner, above the imaginary line of x=y. It might be that those passengers are aware of the delays, and that they are actively using some kind of information to reduce their open waiting time.

From the same diagrams, it is possible to divide the passengers into groups on the behalf of their waiting time strategy, in this case their arrival time strategy. The objective of the grouping is to create a foundation to give better estimates on the passengers' average waiting time, not to conclude on what strategy they use. From the diagrams we can see that the arrivals has centers of gravity in the upper left corer, and along and below the imaginary line of x=y. Hence, the passengers can be divided into two groups. Figure 9 illustrates this. Passengers who is waiting less than expected categorize the upper group, and passengers who probably plan their arrival based on the timetable categorize the lower group. Passengers who arrive randomly can be in both groups.

Figure 9: Passenger arrivals. Dividing passengers into two groups depending on their time of arrival.



The passengers in the upper group experience a shorter waiting time for one of three reasons. 1) They arrive randomly to the bus stop, 2) they traveled with the bus prior to the one they have planned, due to large bus delays, or 3) they use real time travel information to reduce their waiting time. Passengers who arrives after the scheduled departure time, because they assume that the bus is delayed, but do not use real time travel information to confirm this, is categorized as random arrivals. Passengers who experience a shorter waiting time due to buses that departure earlier than scheduled is not included in the group of passengers who experience a shorter waiting time than expected.

The results indicate that the headway affect how passengers plan their arrival to the bus stop. The share of passengers who experience a shorter open waiting time than expected is decreasing with larger headways (Table 2). This indicates that the amount of passengers who plan their arrival based on the timetable is larger at larger headways, which leads to longer open waiting time. Moreover, delays will have a greater effect on passengers traveling at larger headways than short.

Table 2: The share of passengers who experience a shorter open waiting time than expected.

Headways	N	The share of passengers who experience a shorter open waiting time than expected.
10-minute	494	46%
15-minute	457	38%
20-minute	194	17%

3.3 Delays

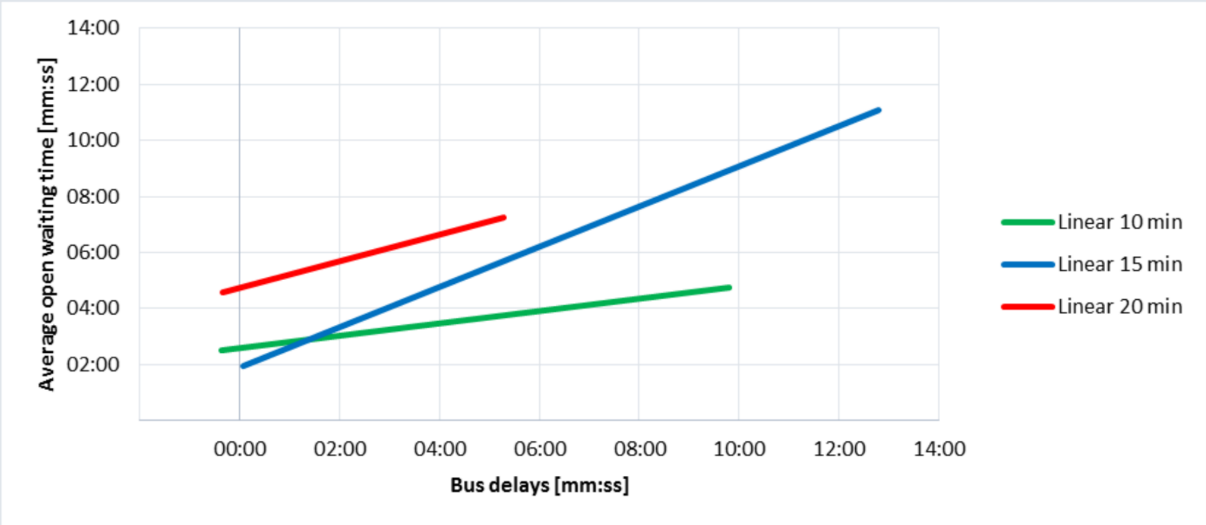
How the waiting time is affected by delays is crucial when waiting time is dealt with in the transport models. Results from this study, shown in Figure 10, shows the average open waiting time for passengers at each headway as a function of the delays. As expected, larger bus delays causes larger average open waiting time. However, the average waiting time increases less than the corresponding bus delay, which indicates that some passengers is aware of the delays, and do not want to plan their arrival with regard to the scheduled bus departure times.

Table 3 summarize key statistics of the registered bus delays. All buses that departure one second or more after the scheduled departure time are defined as delayed.

Table 3: Registered bus delays

Headway	N buses	% Delays	% Delays > 1 minute	Average delay	Max delay
10 minutes	131	95%	81%	02:43	09:48
15 minutes	96	100%	82%	03:19	12:47
20 minutes	94	92%	64%	01:25	05:17

Figure 10: Average open waiting time as a function of bus delays.



From Figure 10 we can see that the average open waiting time may be described in the form of W=a+b*delays, where a and b is either constant or a function of the headways. However, since the average waiting time at 15-minute headways differ from the two others, it is not suitable to develop a universal expression from this data set.

Passengers unaware of delays will experience longer open waiting times. Hence, there are reasons to believe that passengers would like to get information about the delays, in order to avoid excess waiting time. However, results from the survey indicate that slightly less than half the passengers is taking bus delays into account in their waiting time strategy. This means that the majority arrive to the bus stops, as if the bus always departure on scheduled time.

To what extent the use of real time travel information is present, and how, and if it is used to minimize the waiting time might be of great relevance. Results from this study show that about 1/3 of the passengers is using real time travel information, and it indicate that the use is larger with increasing uncertainty whether the bus is delayed or not. This is found to be the most relevant condition for whether the real time travel information is used. The results also indicate that the use is increasing logarithmically with increasing length of the delays. However, the last statement is based on the numbers of passengers who experience a shorter waiting time than expected, and there is no guarantee that these are using real time travel information. How the use will effect the waiting time in detail is still not clarified, but it is expected that the average waiting time will decrease with increasingly use. The study indicates that the passengers who use real time travel information does not have the need, or wish, to include a buffer time, which will be explained in the next section.

3.4 Preferred waiting time

In the light of that passengers are planning their arrival according to bus departure times, we can assume that they have budgeted for a waiting time of a given length. It can be interpreted as a safety margin; the amount of time they want to arrive before the bus departure. There is no reason to believe that passengers wants to wait for a longer time than their desired buffer time, hence it will be mentioned as the preferred waiting time. The length of the preferred waiting time varies among passengers from zero up to several minutes.

The results show that only 10% of the passengers prefer to arrive less than one minute before the bus departures, which match the observed open waiting times at 15- and 20-minute headways (Figure 2 and Figure 3). Despite longer waiting times at larger headways, there is found no noteworthy differences in preferred waiting time for passengers at different headways. The average of 2 minutes seems to apply to trips at all headways and all travel purposes. The only factor that affects this value is the degree of whether the trips were planned and regular. Passengers who mostly travelling with the same bus, and thus have been able to create their own waiting time strategy, are planning for a larger safety margin, than for those who doesn't have, or are not able to make use of a strategy for a particular trip.

3.5 Time costs for waiting time

This study indicates that the open waiting time, and extra waiting time due to delays has a higher cost for the travelers than the hidden waiting time, as well as the other parts of a public transport trip. This is based on what part of a public transport trip passengers value the most and least. Table 4 shows how many passengers (in percentage) who valued each part of the trip with highest and lowest time costs.

Table 4: Passengers' evaluation of the different stages of the waiting time.

	Hidden waiting time	Open waiting time	Extra waiting time	Access time	Time aboard the bus, with a seat
Highest time cost	10%	30%	43%	2%	15%
Lowest time cost	23%	6%	5%	3%	64%

The results indicate that the time aboard has a higher cost for passengers travelling at larger headways, and that the cost for extra waiting time is higher for those who experience delays more often. Other coherences is difficult to find from this data.

3.6 Other strategy elements

By varying the length of the access time, the passengers is able to fix the length of their open waiting time. This is often seen in the context of that if you are late for the bus, you are able to reduce your access time (e.g. by running instead of walking). This principle also works the opposite way, if you want to reduce the time you are waiting at the platform.

About 25% of the passengers include variable access time in their waiting time strategy. In average, they are able to vary their access time by more than 4 minutes.

4 Discussion

The study's aim to reveal if the present modelling of waiting time is suitable for low-frequency services, and how it, if necessary, could be modeled in a way which gives better approximations of the real waiting time costs. Todays models use the assumption of uniform passenger arrivals, and the average waiting time of $W=h/2$ then includes both the open and hidden waiting time. The registrations reveals the passengers' open waiting time, and results from the survey reveals if, and how, any other factors than the open waiting time affect the passengers' cost of waiting time. Because the arrival distribution is far from uniform, and there is a high degree of planning, no formula containing an element of $0{,}5E[h]$ is suitable to describe the waiting time in low-frequency services.

4.1 Validity and representativeness

We can assume that results from this study will be representative for public transport services with low frequency in societies that is similar to the Norwegian. However, the climate probably has a significant influence, which might lead to differences. Low temperatures, wind, and precipitation is shown to have negative effect on the passengers' waiting time, which increases the time cost. As the registrations were conducted at winter, there is reasons to believe that most of the passengers did a greater effort to minimize their waiting time then, than at other times of year.

The study aimed solely at passengers' first waiting time and for trips starting at home. This should be taking into account if dealing with waiting time in other situations, mostly because the possibility to plan the waiting time would be different.

In this study, it has been mentioned that W=h/2 fits for small headways but not for large. However, the question about where random passenger arrivals is appropriate, and what is the limit between small and large headways, is not discussed. Observations of passengers in Greater Manchester suggested that random passenger arrivals was valid on headways up to 12 minutes (Seddon and Day, 1974, found in McLeod, 2007). Results from our study, show that the arrival distribution at 10-minute headways is far from uniform distributed. Ergo, random arrivals is not valid here. Because we live in a time-controlled society, the presence of real time travel information, and that the arrival distribution at 10-minute headways is far from uniform, the upper limit for headways where random arrivals is valid is much lower than 10 minutes. The limit may be at 5-minute headways, but it may also be even lower because most passengers do not want to face excess waiting time.

4.2 Waiting time, hidden waiting time, and time costs

Modelling the waiting time for public transport passengers is not easy. In everyday speech, the waiting time is referred to time spent at a bus stop waiting. However, this time is not sufficient to include all inconveniences passengers experiences when traveling with public transport, because they are not able to travel whenever they want. In order to cover those inconveniences in the models, the waiting time is defined as half the time between departures. This is a good representation of the travel costs in conjunction with waiting time in high frequency services. However, because the inconveniences of not being able to travel whenever you want at larger headways is increasing, this representation is unsuitable.

The incorrect approximations of the real travel costs exist because of the assumption of uniform arrivals, which leads to unlikely long waiting times in low-frequency services. Even though it is a matter of course that not the entire waiting time of W=h/2 takes place at the bus stop, there is only one time cost parameter used for the entire waiting time. Even though this time cost decreases at longer waiting times(Samstad et al., 2010), this does not give a good representation for the real travel costs at low-frequency services. One solution is to split the waiting time into different stages based on what form the waiting time has, and find the duration and the time costs of each stage. Division into hidden-, open-, and extra waiting time due to delays would probably be appropriate.

Waiting time at public transport trips usually splits into hidden and open waiting time. However, in todays transport models the waiting time is not separated, and is described by W=h/2. Taking into account that the preferred open waiting time, and the actual open waiting time is approximately the same for passengers at all headways, it is in fact the hidden waiting time that is the reason for calculating different travel demands at different headways. However, what is hidden waiting time, and is it present at all public transport trips?

The hidden waiting time will only be present if there is time between the point of time you want to travel, and the point of time the trip starts, because you are not able to travel whenever you want. When a passenger knows the bus departure time, and start the trip in accordance to this, the hidden waiting time in the start of the trip will be non-existent in many situations. In addition, in most situations when a passenger encounters hidden waiting, he is able to convert this into longer open waiting time and even access time. This results in that the number of passengers who experience a considerable hidden waiting time is low.

Viewed in this light, and because it is difficult to measure the duration of the hidden waiting time each passenger are experiencing, and even worse to give it a time cost, it should be considered to use other methods to calculate different travel demands at different headways.

There is reasons to believe that extra waiting time at the platform due to bus delays has a higher time cost than the planned open waiting time. This is because the passengers might not have budgeted for this waiting time, and that it can causes other inconveniences beyond the travel itself. A study conducted in Oslo and its suburbs (PROSAM, 2010) have found that the time cost for the delays is more than three times higher than for the waiting time. However, this value does not state at what part of the journey the delays occurs. It might be that this time cost will not be the same whether you are on the bus, or at the platform waiting. In addition, the waiting time in the same study is defined as half the time between departures, which not reflect the true cost of open waiting time.

In our study, there was indicated only a small difference between regular open waiting time and extra waiting time, regarding what has the highest time costs. Maybe these questions were formulated poorly, so that the passengers did not understand the difference between those two options. However, because the cost of delays is assumed much higher than for the open waiting time, and the fact that there were more passengers who valued extra waiting time the most, further investigations on this topic is recommended.

4.3 Delays and strategies

To what extent the use of real time travel information is present might be important in order to provide a good approximation of the real travel costs in the transport models. This is seen in the context of that passengers should be divided into groups according to which waiting time strategy they use, and hence the duration of their waiting time. An appropriate grouping will consist of three groups; 1) random arrivals, 2) arrivals based on the timetables, and 3) arrivals based on use of real time travel information. It is reasonable to believe that passengers using real time travel information are those who aims for, and is experiencing the shortest waiting times, and that their waiting time are least affected by bus delays. Passengers who use the timetable is expected to arrive few minutes ahead of the scheduled departure, and is vulnerable for delays. The objective of the grouping is to create a foundation that gives better estimates on the passengers' average waiting time. Hence, it should be based on their arrival in accordance with the actual and scheduled bus departure time (like in Figure 9), not on what strategy each individual actually used.

An expression for the average waiting time for passengers in each of the three groups, which might include headway and delays, should be developed. The next step is to apportion the passengers into the three group. The grouping may differ between travel purposes, time of day, headway, etc., and hence it should not be static. The result is that we now have three values for the waiting time, which will when weighted according to passenger numbers, give a good representation of passengers' waiting times at low-frequency services, which will replace the existing value of W=h/2.

The arrival registrations is performed on passengers' first waiting time, for trips starting at home. It is expected that most of the registered passengers is frequent public transport users, which indicate that they have great opportunities to plan their trip, and make use of a waiting time strategy. Probably, it is by such trips passengers would have the greatest opportunities to plan their waiting time. On other trips, e.g. when travelling home in the afternoon, it is probably more difficult for many passengers to start their trip at the exact same time every day, which of course will affect their waiting time.

It is reasonable to believe that the costs for the open waiting time is larger during the cold Norwegian winter, which was present when the registrations were conducted. 18% of the passengers in this study answer that the inconveniences of waiting time is larger at bad, or cold weather (63% among those who answered that the inconveniences were not always the same). If the time cost for waiting is bigger, it may be that the passengers is extra attentive about reducing the length of the open waiting time during such conditions. This leads to that the observed waiting times in this study might be shorter than if the study was conducted another time of year. The extent of passengers who use variable access time in their strategy, might also be higher in other seasons for the same reasons.

Increased use of real time travel information will probably lead to shorter waiting times. Results from this study show shorter average waiting times than in a study conducted in Oslo only 6 years ago, where the average was found to be around 5-6 minutes for all headways (Ruud et al., 2010). Probably, increased use of real time travel information might be one of the reasons for this. Moreover, the waiting time costs for public transport passengers will probably decrease even more in course of the next years.

5 Conclusion

There are clear evidence that passengers plan their arrival to the bus stops in order to reduce their waiting time, when travelling with public transport in low-frequency services. The average open waiting time is less than half the time between departures, and the hidden waiting time is probably considerably less than previously expected. This indicates that the waiting time used in todays transport models is overestimated. The average open waiting time is found to be 0.32*h at 10-minute headways, and it increases with larger headways. However, the coefficient slightly decreases.

Future transport models should be based on dividing the public transport passengers in three groups, depending on their waiting time strategy. The three groups are 1) random arrivals, 2) arrivals based on the timetable, 3) arrivals based on the use of real time travel information. A function for the average waiting time among the passengers in each group, which includes delays and headways, should be developed. These formulas has the intention to replace W=h/2. The next step is to apportion the passengers into the three groups. The classification should not be static, because the passengers waiting time strategy might differ between different travel purposes, time of day, headway, and more. Using this method, the transport models have more accurate input data for the waiting time, which will provide better approximations of the real travel costs for public transport trips in low-frequency services.

Passengers who use real time travel information is expected to have shorter waiting time. With increasingly greater use of this technology, the average waiting time is expected to decrease, which leads to even greater need of new methods of dealing with waiting time in the transport models in the future.

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