Investigating the Relationship of Service Headway to Wait Time in the Dallas-Fort Worth Metropolitan Area

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1 BACKGROUND

The current practice in transit modeling is to consider that the passenger initial wait-time at a transit stop is equal to half the service headway. This calculation assumes that the passenger wait time for a transit route is based on the reliability of the specified transit route. If large wait times that are assigned to express bus or commuter rail services that have longer headways negatively affect the ridership on those routes, modelers may choose to modify the formula to cap the initial wait-time to the smaller of half the headway and a fixed constant.

The modeling of wait time has been addressed in some studies by incorporating the variability in passenger arrivals into the wait time calculations along with the service headway [1]. Past studies show that there may be different types of travelers for different types of services[2]. Some passengers actually plan their trip to minimize their initial wait-time at the transit stop; these trips are normally associated with the passengers that use services with longer headways or are regular users of the system. These passengers seldom start their journey on a spur of the moment and have a non-random arrival at the transit stop. On the other hand, the passengers of services that run on a shorter headway know that there will always be a service vehicle available at their transit stop within a couple of minutes of their arrival time. Therefore, they do not have to plan their journey as meticulously as the first group of passengers. This group of passengers will randomly arrive at the transit stops.

The North Central Texas Council of Governments (NCTCOG) modeling group wanted to investigate whether or not these same passenger variability patterns applied to the DFW area where the transit demand is less than 1% of the total daily trips. Using our experience with travel in the Dallas-Fort Worth Modeling Area, it is believed that regardless of service headway, the passengers normally plan their trips to minimize initial wait time. As a result, NCTCOG developed a wait time study to determine whether the wait time at transit stops is dependent on transit service headway. In this study, a wait time survey was developed to sample bus routes, commuter rail, and light rail in the Dallas-Fort Worth modeling area.

2 SAMPLING METHODOLOGY

Although there are three transit agencies serving the Dallas-Fort Worth metropolitan area, this study was performed on the Dallas Area Rapid Transit (DART) coverage area since the 2008 onboard survey in the Fort Worth Transportation Authority (FWTA) system and Denton County Transportation Authority (DCTA) had already addressed this question. Therefore, the sampling universe was defined as the DART transit system of express and local buses, light-rail transit (LRT), and the Trinity Railway Express (TRE) commuter rail.

2.1 Sample Size

The sample sizes were calculated for five groups of service headways: 10-15, 15-20, 20-30, 30-45, and > 45 minutes. This ensured that sufficient samples were obtain based on the potential variances in the initial wait times in each group. This range covers the possible service scenarios in the DART system.

1. Share of Random Arrivals

The share of random passenger arrivals in each headway group was defined based on a recent study performed in Australia by Booz Allen Hamilton (BAH) consultants [4].

2. Service Headway Variation
   The Coefficient of Variance (CV) of the service headway for each of the groups was calculated based on the results of the study outlined in reference [3].

3. Expected Random Wait-Time
   The expected wait-time for the random passengers was calculated as follows:
   0.5 * Average Headway of each group * [1 + (CV^2)]

4. Share of Non-Random Arrivals
   This share is equal to 1 – (Share of Random Arrivals)

5. Expected Non-Random Wait-Time
   This was taken from the study in reference [4] for each of the groups.

6. Expected Wait-Time
   The expected wait-time for each group is equal to the weighted average of the expected value of the wait-times of the random and non-random arrivals.

7. Maximum Wait-Time
   The maximum wait-time has been set equal to the average headway of each group.

8. Wait-Time Variance
   It has been assumed that the initial wait-times follow a normal distribution and hence the maximum wait-time is 3.5 times the standard deviation from the mean.

9. Wait-Time Coefficient of Variance
   This is calculated through dividing the wait-time standard deviation by the mean wait-time for each group.

10. Uncorrected Sample Size
    The uncorrected sample size was calculated for all possible combinations of the transit services.

    Formula:

    $$CV^2 * Z^2 / E^2$$

    where:

    CV = wait-time coefficient of variance for each group (from step 8);
    Z = standard normal variable at 90% confidence interval (1.95);
    E = margin of error (5.00%)

The sample sizes were then corrected based on the number of first boardings of each of the service combinations.

2.2 Route Selection

The LRT has an average peak-hour model service headway of 13 minutes. The number of initial wait-time samples needed for this service is 65. In the region, there are two light rail lines, the DART Blue Line and the DART Red Line; both of these lines were selected to be included in the survey.

The TRE has an average peak-hour model service headway of 20 minutes. Therefore, the required number of initial wait-time samples for this service is 170.

The total samples needed for the DART bus service, with an overall average headway of 32.5 minutes (including the express buses), was 500. Two bus routes were selected for each of the following headway groups: 10-15, 15-20, 20-30, 30-45, and > 45 minutes. The bus routes were selected based on their ridership, geographical service area, and service type. The ridership was used to ensure that enough ridership is available to produce the required sample size. The service type was reviewed to maintain a balance of local and express route types contributing to the sample. After the routes were chosen, the entire set of routes was compared to the geographical service area to confirm that the sample is a representation of the system.

3 DATA COLLECTION

The data collection was conducted during one week in May 2009. It was conducted from the hours of 6:00 a.m. to 8:00 p.m. and each surveyed route was evaluated for an entire day, so that the a.m. peak, p.m. peak, and off-peak periods would be sampled.

4 QUESTIONNAIRE

The wait time study was conducted through personal interviews with the transit users. The requirements for the interviewer were to record the following: the route number, time of day, the route the respondent transferred from, the wait time, and the trip purpose. In order to encourage participation by allowing the interview to be brief, the questionnaire included only four questions. The surveyor would automatically record the date, route number, and time for each questionnaire. The first question asked the user whether the rider transferred from another bus/train; this information would be used to distinguish between initial wait time and transfer wait time. The second question asked the rider to provide their wait time. The last two questions asked for the origin type and destination type so that trip purpose could be determined. The questionnaire is shown in

Exhibit 1.

Exhibit 1: Wait Time Study Questionnaire

Surveyor Name:_____ **Survey Date:**_____
NCTCOG (DART/TRE) On-Board Wait Time Survey

Assignment #: _____ **Route #:**_____ **Time:**_____ ❍ AM ❍ PM

1) Did you transfer from another bus/train to get to THIS VEHICLE: ❍ No ❍ Yes

2) How many minutes did you have to wait at the bus/train stop for THIS VEHICLE:

❍ 5 or less ❍ 6-10 ❍ 11-15 ❍ 16-20 ❍ More than 20

3) What type of place are you COMING FROM NOW:

❍ Home ❍ Work ❍ College / University Student ❍ K-12th Grade Student ❍ Shopping

❍ Social / Recreation ❍ Medical / Hospital ❍ Restaurant (not for work) ❍ Other_____

4) What type of place are you GOING TO NOW:

❍ Home ❍ Work ❍ College / University Student ❍ K-12th Grade Student ❍ Shopping

❍ Social / Recreation ❍ Medical / Hospital ❍ Restaurant (not for work) ❍ Other_____

5 ANALYSIS

The survey produced 1,933 completed surveys which included 1,349 bus surveys, 392 LRT surveys, and 192 TRE surveys. The completed survey goal for each mode was reached. Using the information recorded in each survey, the results were analyzed by aggregating by headway group, trip purpose, and time of day.

The table in Exhibit 2 shows the average initial wait time and average transfer wait time for each headway group. The LRT (Light Rail Train) headway is 13 minutes, and the average TRE Commuter Rail headway was 20 minutes. From this table, one can see that the average initial wait time was consistent between headway groups and ranged only from 5.53 – 7.43. Similarly, the average transfer wait time ranged from 8.11 – 9.88 with the only exception being the LRT which had a 6 minute average transfer wait time.

Exhibit 2: Initial Wait Time and Transfer Wait Time by Headway Group

Headway Group	Avg Initial Wait (min)*	Avg Transfer Wait (min)*

10-15	5.81	8.91
15-20	5.53	8.32
20-30	6.00	9.28
30-45	6.32	8.08
> 45	7.43	9.88
LRT (13)	5.68	5.96
TRE (20)	6.70	8.11
TOTAL	**6.20**	**8.07**

* Wait Time from the headway ranges was calculated using the median value of each headway range(0-5, 6-10, 11-15, 16-20) and 25 minutes for the range of > 20 minutes.

Exhibit 3 displays a table of the average initial wait time and average transfer wait time for each trip purpose. Overall there was little variation between the initial and transfer wait time by trip purpose, with the average wait time by trip purpose ranging only from 5.37 – 8.48 minutes.

Exhibit 3: Initial Wait Time and Transfer Wait Time by Trip Purpose

Trip Purpose	Avg Initial Wait (min)*	Avg Transfer Wait (min)*
HBW	5.37	7.72
HNW	6.88	8.48
NHB	7.67	7.98
TOTAL	**6.20**	**8.07**

* Wait Time from the headway ranges was calculated using the median value of each headway range(0-5, 6-10, 11-15, 16-20) and 25 minutes for the range of > 20 minutes.

Exhibit 4 displays a table of the average initial wait time and average transfer wait time by trip purpose and time of day. The Home-Based Work trip purpose for the AM time period had a smaller average initial wait time than any other category. Overall there was little variation between the initial and transfer wait time by trip purpose, with the average wait time by trip purpose ranging only from 5.37 – 8.48 minutes.

Exhibit 4: Initial Wait Time and Transfer Wait Time by Trip Purpose and Time of Day

Trip Purpose	Time of Day	Avg Initial Wait (min)*	Avg Transfer Wait (min)*
HBW	AM	3.71	6.52
HBW	NOON	6.20	7.32
HBW	OP	5.77	9.00
HBW	PM	6.30	7.15
HBW	**TOTAL**	**5.37**	**7.72**
HNW	AM	5.80	7.95
HNW	NOON	7.25	8.90
HNW	OP	7.02	8.38
HNW	PM	7.28	8.61
HNW	**TOTAL**	**6.88**	**8.48**

NHB	AM	6.63	7.92
NHB	NOON	10.24	9.61
NHB	OP	7.81	8.40
NHB	PM	5.34	6.07
NHB	**TOTAL**	**7.67**	**7.98**
TOTAL	**TOTAL**	**6.20**	**8.07**

* Wait Time from the headway ranges was calculated using the median value of each headway range(0-5, 6-10, 11-15, 16-20) and 25 minutes for the range of > 20 minutes.

The wait time ranged from about 6 minutes to 8 minutes for routes whose headway ranged from 10-15 to > 45 minutes. As a result of the output, it was determined that wait time has little to do with the average headway of the route.

6 CONCLUSION

Based on the results of the wait time study, little difference was found in the initial wait time by trip purpose, time of day, or headway group. Instead, the findings show that regardless of headway, most passengers tend to minimize their wait time and the average wait time for all services is closer to 8 minutes instead of half the headway.

REFERENCES

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[3] Mishalani, Rabi G., McCord, Mark M., Wirtz, John, “Passenger Wait Time Perceptions at Bus Stops: Empirical Results and Impact on Evaluating Real-Time Bus Arrival Information”, Journal of Public Transportation, Vol. 9, No.2, 2006.

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