Effect of Fare Policies on Dwell Time

Case Study for the Pittsburgh Region

Mark Egge, Zhen (Sean) Qian, and Amy Silbermann

Bus fares may be collected when passengers board or immediately before they alight. Little work has been done to quantify the impacts of entry fare and exit fare policies on passenger stop delay, namely the dwell time. The Port Authority of Allegheny County (PAAC), Pennsylvania, is one of few mass transit systems to currently employ both entry fare and exit fare policies. PAAC's alternating fare policy offers an ideal natural experiment for investigating the effect of fare collection policy on dwell time. PAAC automated passenger counter and automatic vehicle location data were analyzed to estimate dwell time under no fare collection and entry fare and exit fare policies. The study found that the choice of fare policy can significantly affect the dwell time associated with fare payment but also that the effect of fare policy varies with route characteristics. The findings suggest that a transit system that seeks to minimize the contribution of fare payment to total trip dwell time may be most effective by operating an entry fare policy on local routes with frequent stops and evenly distributed ridership and an exit fare policy on express and bus rapid transit routes with fewer stops and substantial passenger movements at major stops.

Bus fares may be collected when passengers board, immediately before they alight, or off the vehicle. Of these options, off-vehicle fare collection results in the least passenger stop delay but requires significant supporting infrastructure (*1*). With regard to on-vehicle fare collection, however, no study yet exists to say whether an entry fare or exit fare policy is better with respect to minimizing delay. The timing of fare collection determines where and how passengers queue to pay their fares as well as the timing of when, in relation to a trip's progress, the delay associated with fare collection is incurred. To date, no study has compared these two fare collection policies, and the result has been a major gap in knowledge in fare policy selection. The research reported in this paper contributes to filling that gap.

Automated passenger counter (APC) and automatic vehicle location (AVL) data enable detailed and robust analysis of passenger stop delay (dwell time) and its constituent components. Previous work has investigated the impact of passenger movement (*2*), fare payment types and crowding (*3*), and bus design (*4*) on overall dwell time. The present study extends current knowledge of dwell time determinants by comparing the impact on dwell time of payment at the time of boarding (entry fare policy) and payment immediately prior to alighting (exit fare policy) and by explicitly separating the portion of dwell time attributable to fare payment from other components of passenger stop delay.

The Port Authority of Allegheny County (PAAC), Pennsylvania, which services the greater Pittsburgh region, is one of a few mass transit systems that currently employ both exit fare and entry fare policies. To accommodate a free zone of ridership in Pittsburgh's central business district (CBD), PAAC alternates its fare collection policy by route direction and time of day. PAAC's varying fare policies offer an ideal natural experiment for investigating the effect of fare collection policy on dwell time.

This study analyzed 2 months of PAAC APC and AVL data to estimate how dwell time varied under scenarios of no fare payment, entry fare policy, and exit fare policy. Regression analysis was used to estimate the marginal contributions of boarding, alighting, and fare payment (if applicable) to total dwell time under each fare payment scenario and across routes with different service characteristics. These marginal contributions were first estimated at the individual stop level. Because the accumulation of small differences in per-passenger dwell times at individual stops may significantly affect a trip's total duration and on-time performance, total trip dwell times were also estimated at the at the aggregate trip level.

This paper orients the policy question of the timing of fare collection in the context of previous research on dwell time, describes the PAAC public transit system that provided the data for analysis, outlines the research methodology, and presents the findings. The paper concludes with a summary of the results, their applicability to other public transit systems, and suggestions for further research.

LITERATURE REVIEW

TCRP Report 165: Transit Capacity and Quality of Service Manual, Third Edition defines dwell time as "the time a bus spends serving passenger movements, including the time required to open and close the bus doors and boarding lost time" (*5*). Dwell time may constitute up to 26% of a bus's total running time (*6*). Passenger loading and unloading times are significant determinates of total dwell time (*3, 4, 7–10*). Other factors that influence dwell time include

- Fare payment method (on vehicle or off vehicle) (*8*),
- Fare type (cash, magnetic card, contactless card) (*3, 10*),
- Use of wheelchair ramps and bicycle racks (*2, 3*),
- Bus type (e.g., low floor, articulating) (*4*), and
- On-vehicle congestion (*1, 3, 8, 9*).

TCRP Report 165 reports an observed range of average per-passenger dwell times of 2.5 to 3.2 s per boarding passenger paying with a

M. Egge, School of Information Systems and Management, and Z. Qian, Department of Civil and Environmental Engineering, Heinz College, Carnegie Mellon University, 5000 Forbes Avenue, Pittsburgh, PA 15213. A. Silbermann, Port Authority of Allegheny County, 345 Sixth Avenue, 3rd Floor, Pittsburgh, PA 15222. Corresponding author: Z. Qian, seanqian@cmu.edu.

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smart card and 1.4 to 3.6 s per passenger alighting from the front door (*5*).

Dueker et al. established a general ordinary least squares model for using APC data to estimate dwell time on the basis of independent variables, including passenger boarding and alighting and use of a passenger lift for mobility-impaired passengers (*2*). Rajbhandari et al. used ordinary least squares regression of the number of boarding and alighting passengers at a stop as well as the number of standees in a vehicle to estimate dwell time (*6*). They evaluated multiple regression models and found the explanatory power of the models to be greatest when vehicle load was included as an interaction term (*6*). Their study did not account for fare collections or fare collection methods but did suggest such an investigation as an area for future research.

Fletcher and El-Geneidy found that bus fare payment methods substantially affected dwell time and that all-door loading and unloading substantially reduced dwell time (*3*). Their paper provides the best existent investigation of the effect of crowding on passenger movements and dwell time. They found that lower numbers of passenger movements at a given stop were significantly more affected by crowding levels than higher numbers of passenger movements were.

To investigate whether complex distance-based fare structures with multiple zones, transfers, and fare amounts increased dwell times associated with fare payment, Guenthner and Hamat studied Detroit's regional bus transit system and found that the use of distance-based fares did not increase overall dwell times (*10*).

Sun et al. used APC data to investigate passenger boarding and alighting times that were based on 2011 APC data from Singapore's public bus system, where passengers both tap on when entering the bus and tap off with a contactless card when alighting (*8*). They found average boarding times of 1.7 to 2.0 s per boarding passenger, and 1.2 to 1.4 s per alighting passenger. Their work also found a critical load factor of 63% of capacity, beyond which friction between boarding and alighting passengers increased total dwell times.

Tirachini and Hensher developed a microeconomic model that compares costs associated with on-vehicle fare collection or validation and those associated with on-platform (off-vehicle) fare collection and validation (*1*). They found that during periods of high demand, slower payment (on-vehicle) systems compounded costs by affecting the operation of other vehicles as well.

Although the costs and components of dwell time are well established in the transportation literature, no study has yet compared the impact on dwell time of entry fare versus exit fare policy.

RESEARCH CONTEXT

PAAC operates 98 hail-and-ride, curb-stop bus routes (Table 1). Fares are collected at the front door (adjacent the driver) by means of contactless tap-and-go cards. Cash payments are also accepted. Most inbound routes operate an entry fare policy and most outbound routes operate an exit fare policy until 7:00 p.m. on weekdays and an entry fare policy otherwise. This alternating policy exists to accommodate a free zone of ridership within the CBD.

To provide this free zone of ridership within the CBD, most buses (excluding Route G2) do not collect fares and use an all-door load policy when operating in the CBD on weekdays before 7:00 p.m. Previous work has found an all-door load policy to significantly reduce dwell times (*3, 11*). For service outside the CBD, typically only the front door is used for boarding and alighting.

TABLE 1 Characteristics of 2015 PAAC System

System Attribute	Value
Bus route	98
Express	25
Key corridor	14
Local	56
Rapid	3
Average weekday ridership	179,361
Fleet size (buses)	726
Revenue service hours	1,391,191

PAAC routes are designated by service type as local, express, rapid [bus rapid transit (BRT)], or key corridor. Key corridor routes connect Pittsburgh's major business and employment centers (the CBD and Oakland) with outlying business districts and neighborhoods. These routes generally resemble local service within the business districts and express service between business districts.

PAAC routes P1 and G2 are BRT routes with contrasting fare policies. Route G2 has an entry fare policy at all times. When outbound, Route P1 operates with an exit fare policy until 7:00 p.m. Both routes connect Pittsburgh's CBD with suburban stations. Key corridor routes 71A, 71B, 71C, and 71D (hereafter 71X) and 61A, 61B, 61C, and 61D (hereafter 61X) connect multiple business zones and suburban neighborhoods.

METHODOLOGY

The present study used linear regression to estimate the contributions of boarding lost time, passenger movement, and fare payment to the total dwell time. Dwell time was first estimated at the level of individual stops, which allowed fare payment time to be isolated from passenger movements by comparison of dwell times within the CBD free ridership zone with dwell times outside the fareless CBD ridership zone. Dwell time was then summed and its constituent components were estimated for complete trips, regressing the number of passengers, completed stops, and route type on dwell time and across different route service types. Estimates of the marginal contributions of each component of dwell time were obtained from the regression coefficients.

For the stop-level analysis, the baseline model was given by

$$Y_i = \alpha + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_3 X_{3i} + \varepsilon_i$$

where

Y_i = dwell time (seconds) at stop i,
α = model intercept term representing average boarding lost time (the time required to open and close the vehicle doors and the delay between the opening of the vehicle's door and the time at which passengers arrive at the door to begin boarding),
β_1 = model coefficient representing average dwell time (seconds) per boarding passenger,
X_{1i} = number of boarding passengers at stop i,
β_2 = average dwell time (seconds) per alighting passenger,
X_{2i} = number of alighting passengers at stop i,
β_3 = average additional dwell time (seconds) attributable to friction (additional delays associated with crowding on the vehicle),

X_{3i} = square of the passenger load in excess of the number of available seats, and

ε_i = error term capturing variance in dwell time caused by factors other than those controlled for by the independent variables, such as usage of a wheelchair ramp and cash payments.

The models that compare the performance of entry fare, exit fare, and no fare within a given route type were specified as

$$Y_i = \alpha + \alpha_1 B_{1i} + \alpha_2 B_{2i} + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_3 X_{3i} + \beta_4 X_{1i} B_{1i} + \beta_5 X_{2i} B_{2i} + \varepsilon_i$$

with additional parameters defined as follows:

α = model intercept term under the no-fare-payment scenario representing average boarding lost time;

α_1 = difference in average lost time under an entry fare scenario, relative to the no-fare-payment scenario;

B_{1i} = binary variable (1 = entry fare payment; 0 otherwise);

α_2 = difference in average lost time under an exit fare scenario, relative to the no-fare-payment scenario;

B_{2i} = binary variable (1 = exit fare payment; 0 otherwise);

β_4 = average dwell time per entry fare payment;

$X_{1i}B_{1i}$ = number of entry fare payments;

β_5 = average dwell time per exit fare payment; and

$X_{2i}B_{2i}$ = number of exit fare payments.

The trip-level analysis utilized a regression model of the general form

$$Y_i = \alpha + \beta_1 X_{1i} + \sum_{p=2}^{16} \beta_p X_{pi} + \varepsilon_i$$

where

Y_i = aggregate trip total dwell time;

α = intercept term representing the average trip dwell time associated with routes of the base type class (express routes and entry fare policy, in this analysis);

β_1 = model coefficient representing the average boarding lost time per stop;

X_1 = number of completed stops during the bus trip;

β_p = pth model coefficient representing the average change in dwell time associated with the route type, interacting with the fare policy type;

X_p = number of passengers served during the trip or the binary variable indicating the route type and fare policy type (see Table 6 for a list of all independent variables); and

ε_i = error term capturing variance in dwell time owing to factors other than those controlled for by stops, passengers, route type, and fare policy.

DATA SET AND RESULTS

This study used weekday APC and AVL data provided by PAAC for September and October 2014. The data were automatically generated by tracking devices installed on PAAC buses. For each designated stop on a route, the data set provided the arrival time, number of alighting passengers, number of boarding passengers, departure time, and total passenger load. Dwell time was defined as the time the door was open and was calculated as the difference between the bus's arrival and departure times at a given stop.

This study benefited from an abundance of data (the data set describes more than 750,000 observed bus dwell times), but there are several limitations in the specificity of the data. In particular, dwell time in the data set is given as the time between doors opening and doors closing, which may exceed the time required for passenger service. For example, the bus operator may leave the doors open during timepoint holding to maintain a target headway or while waiting at a traffic signal. Dwell time is also affected by circumstances not specifically identified in the data set, such as the use of a wheelchair ramp or bicycle rack and cash fare payment, which was not separated from contactless smart card payments in the data set.

Observations were removed from the data set when the circumstance (e.g., the last stop of a trip) or the data (e.g., observed dwell times of greater than 30 s per passenger movement) suggested that the observed dwell time was not constrained by passenger movements. Observations were removed for stops with zero passenger movements; for the first and last stops of each route, where dwell time is not constrained by passenger movement; and when the observed data suggested sensor error, timepoint holding, or other waiting with doors open unrelated to passenger movement. The resulting data set describes 753,960 stops across 41,605 trips for routes P1, G2, 71X, and 61X. Each observation's fare policy (no fare, entry fare, exit fare) was derived from PAAC fare rules.

STOP-LEVEL DWELL TIMES

The initial analysis investigated the determinants of dwell time for BRT routes P1 and G2 and for key corridor routes 71X and 61X. Collectively, these routes represent the routes with the highest ridership in the PAAC system and cover representative geographic and traffic conditions (Figure 1 and Table 2).

Regression models estimating dwell time components were created as follows:

- Baseline entry fare model: BRT Route G2, for which all stops are entry fare stops (Table 3);
- Baseline exit fare model: BRT Route P1, limited to exit fare observations only (Table 3);
- BRT comparison model: fare policy regression for all stops on routes P1 and G2 under varying fare policies (Table 4); and
- Key corridor comparison models: comparison of within-route performance for Key Corridor Routes 71X under contrasting fare policies and Key Corridor Routes 61X under contrasting fare policies (Table 4).

Table 3 presents the baseline model results for entry fare BRT Route G2 and exit fare BRT Route P1. Table 3 also presents the dwell time estimates from selected works under similar modeling assumptions. For entry fare BRT Route G2, each stop had a fixed dwell time of 4.81 s, with an additional 3.63 s per boarding (and paying) passenger, and 0.99 s per alighting passenger. The dwell time per fare payment is implied in the difference in time between boarding and alighting (2.64 s per entry fare payment, in this case). For BRT Route P1, when operation was under an exit fare policy, each stop had a fixed dwell time of 5.32 s with an additional 1.61 s per boarding passenger and 3.23 s per alighting (and paying) passenger. The implicit dwell time per exit fare payment was 1.62 s.

Table 4 presents the results for the fully specified stop-level model. All coefficients are given in seconds of dwell time. The BRT comparison model compared routes G2 and P1 directly and showed

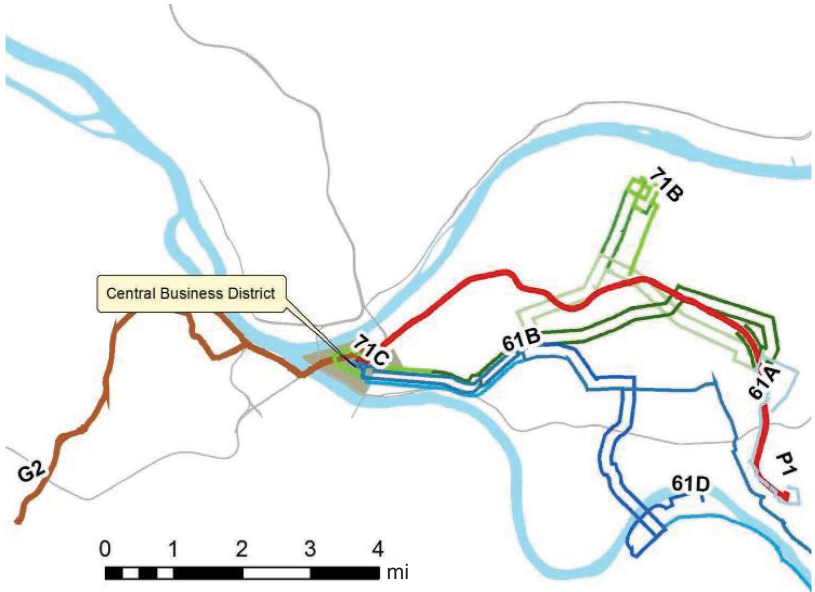

FIGURE 1 Stop-level dwell time regression route map, Pittsburgh.

a marginal dwell time of 1.18 s per boarding passenger, 1.12 s per alighting passenger, 2.72 s per entry fare payment collected, and 2.06 s per exit fare payment collected. For these BRT routes, an exit fare policy was found to be 0.66 s faster per payment than an entry fare policy.

For key corridor routes 71X and 61X, the results showed respective average boarding times of 2.20 and 2.43 s per passenger, alighting times of 1.61 and 1.65 s per passenger, entry fare payment times of 1.28 and 1.00 s per passenger, and exit fare payment times of 1.59 and 1.44 s per passenger. For these key corridor routes, an exit fare policy was found to be 0.31 and 0.44 s slower per payment than an entry fare policy.

Total per-passenger dwell time can be compared by adding per-passenger average boarding time, alighting time, and fare payment

TABLE 2 Summary Statistics for Stop-Level Dwell Time Regression Routes

Route	Fare Policy	Average Weekday Riders	Number of Stops	Observed Average Ratio of Dwell Time to Total Duration	Type	Peak Headway (min)
P1	Alternating	12,850	13	0.23	BRT	3
G2	Entry	3,929	15	0.09	BRT	8
71X (average)	Alternating	20,743	74	0.11	Key corridor	5
61X (average)	Alternating	20,193	79	0.10	Key corridor	5

TABLE 3 Stop-Level Dwell Time Regression Results with Selected Comparisons

Attribute	Term	Baseline Entry Fare Model (Route G2)	Baseline Exit Fare Model (Route P1)	TCQSM (*5*)	Fletcher and El-Geneidy, Traditional Model (*3*)	Dueker et al., Dwell Time Without Lift Operation (*2*)	El-Geneidy and Vijayakumar (*4*)
Boarding lost time (intercept)	α	4.81	5.32	2.4–3.5	9.42	5.14	10.89
Dwell time per boarding passenger	β_1	3.63	1.61	2.5–3.2	3.11	3.48	4.05
Dwell time per alighting passenger	β_2	0.99	3.23	1.4–3.6	1.86	1.70	2.73
Friction	β_3	–0.013	–0.018	na	0.002	0.069	na
Model R^2		.570	.744	na	.668	.668	.418

NOTE: All coefficients given in seconds of dwell time. na = not applicable.

TABLE 4 Stop-Level Dwell Time Regression Results

Attribute	Term	BRT Comparison Model (P1 and G2) Estimate	SE	71X Key Corridor Comparison Model Estimate	SE	61X Key Corridor Comparison Model Estimate	SE
Boarding lost time (intercept)	α_0	7.81	0.159	8.608	0.089	8.12	0.085
No fare boarding lost time		(base)		(base)		(base)	
Entry fare boarding lost time	α_1	−3.08	0.167	−6.08	0.089	−5.46	0.086
Exit fare boarding lost time	α_2	−1.89	0.200	−4.85	0.092	−4.58	0.088
Dwell time per boarding passenger	β_1	1.18	0.017	2.20	0.012	2.43	0.012
Dwell time per alighting passenger	β_2	1.12	0.013	1.61	0.009	1.65	0.009
Friction	β_3	−0.012	0.001	−0.013	0.001	−0.008	0.001
Dwell time per entry fare payment	β_4	2.72	0.021	1.28	0.015	1.00	0.016
Dwell time per exit fare payment	β_5	2.06	0.019	1.59	0.016	1.44	0.017
Model R^2		.668		.418		.424	

NOTE: All coefficients are given in seconds of dwell time. All estimates significant at an $\alpha = .001$ level. SE = standard error.

time. Figure 2, which presents this comparison, shows that, for both route types, marginal dwell time per passenger was markedly decreased within the CBD, where no fares are collected, relative to either an entry or an exit fare policy.

TRIP-LEVEL DWELL TIMES

The stop-level regression results suggested that the impact of an exit fare policy varied with route type and corresponding patterns of ridership. To investigate this hypothesis, the data set was expanded to include all 76 PAAC routes that employed an alternating fare policy. These routes are described in Table 5 and shown on a map by type in Figure 3.

The data were prepared for trip-level analysis by assignment of a unique trip identifier to each observation on the basis of date, route, direction, and departure time. Trip statistics were calculated by summing dwell time and passenger movements and counting completed stops for each unique trip. Observations for incomplete trips were removed. The resulting data set described 106,749 completed trips across 76 routes (Table 5). Route type was assigned according to PAAC designation.

To investigate the impact of fare policy on aggregate trip dwell time, a regression of total trip dwell time was taken on the number of passengers, the number of stops with passenger movements, and interaction terms between fare policy and route type. Table 6 presents the results of this regression.

Each stop was found to contribute a fixed dwell time of 5.29 s attributable to boarding lost time. In the express route base case, each passenger was associated with a marginal increase in dwell time of 2.74 s. Relative to express routes, the key corridor, local, and BRT routes saw a respective additional 1.58, 1.47, and 2.08 s greater dwell time per passenger (4.32, 4.21, and 4.82 s in absolute terms, respectively).

Local routes saw a marginal increase of 0.66 s in dwell time per passenger associated with an exit fare, and BRT routes saw a marginal decrease of 1.10 s per passenger. Key corridor routes saw an increase (not statistically significant) of 0.39 s in dwell time per passenger—somewhere between the effect of exit fare on local routes and BRT routes. This finding is consistent with the results of the analysis of stop-level dwell time.

Converting exit fare policy to entry fare can bring in benefits for most local and key corridor routes but not necessarily for BRT routes. The main reason is the ridership characteristics of those routes. BRT routes tend to carry passengers in main-demand attraction–production locations such as Pittsburgh's CBD. Stops with high passenger movement exhibit less friction between walking passengers and standing passengers. BRT routes, which have infrequent

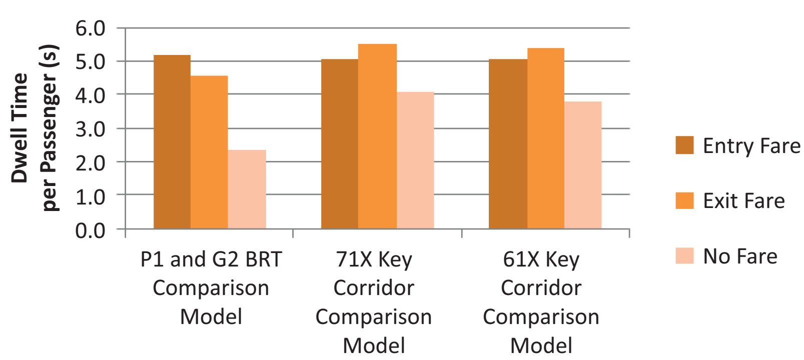

FIGURE 2 Average dwell time per passenger, by fare policy.

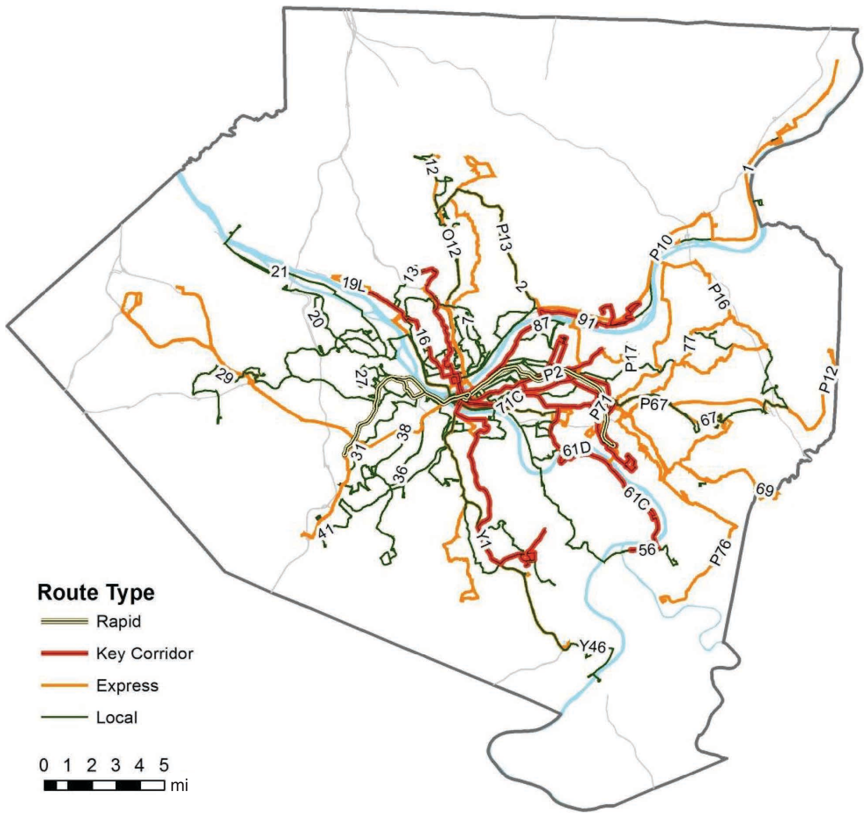

FIGURE 3 Trip-level dwell time regression routes, Allegheny County.

and high passenger movement stops, are less affected by friction within the vehicle than are local and key corridor routes, where frequent small quantities of alighting passengers encounter difficulty walking through standing riders to reach the front door and pay. Therefore, for most local routes, where ridership is more evenly distributed across stops, the benefits of an entry fare over an exit fare are more pronounced.

For express routes, the point estimate of the dwell time impact of an exit fare policy shows a negative coefficient, indicating lower average dwell times under an exit fare policy. Although the coefficient estimate is not statistically significant, the negative coefficient is consistent with the intuition that routes with strong peak direction and infrequent, high-volume stops may benefit from an exit fare policy.

For BRT routes and local routes, an exit fare policy was associated with an average reduction in total-trip dwell time of 197.32 and 19.33 s, respectively. This is possibly because passenger movements are more significant during the outbound afternoon peak hours when an exit fare policy applies.

CONCLUSION

This paper provides the findings of the first known investigation of the impact on dwell time of entry fare policies versus exit fare policies. The study used APC and AVL data from the Pittsburgh region to analyze the impact of fare policy on passenger stop delay and found that the choice of fare policy can significantly affect the dwell time associated with fare payment. The impact of fare policy varied with route characteristics. For most routes, an entry fare was found to be preferable to an exit fare in minimizing delay. For BRT routes, however, or other routes with fewer stops and substantial passenger movement at major stops, an exit fare is predicted to minimize payment-related delay. A transit system that seeks to minimize the

TABLE 5 Summary Statistics for PAAC Routes with Alternating Fare Policy

Route Type	Route Count	Mean Dwell Time (s)	Mean Duration (min)	Mean Passengers per Trip	Mean Stops per Route	Mean Passenger Stops	Dwell Time/Duration Ratio (%)
Local	39	191.9	48:17	26.1	63.4	16.7	6.6
Key corridor	13	308.0	49:31	42.5	69.5	24.7	10.4
Express	22	182.2	46:22	29.3	45.2	15.0	6.5
Rapid	2	355.4	26:37	41.6	12.3	9.2	22.3

TABLE 6 Regression Results for All PAAC Routes with Alternating Fare Policy

Attribute	Trip Dwell Time Estimate (s)	SE	Significance Level[a]
Intercept (express routes, entry fare policy)	20.62	4.75	****
Key corridor routes	–44.58	5.25	****
Local routes	–27.66	5.15	****
BRT routes	192.34	7.22	****
Exit fare policy			
Express routes (base case)	8.67	6.54	
Key corridor routes	20.60	7.25	***
Local routes	–19.33	7.17	***
BRT routes	–197.32	9.83	****
Stops	5.29	0.09	****
Passengers			
Express routes (base case)	2.74	0.14	****
Key corridor routes	1.58	0.14	****
Local routes	1.47	0.15	****
BRT routes	2.08	0.18	****
Passengers, exit fare policy			
Express routes (base case)	–0.19	0.20	
Key corridor routes	0.39	0.21	*
Local routes	0.66	0.22	***
BRT routes	–1.10	0.25	****

NOTE: R^2 = .43.
[a]Significance: *α = .1; **α = .05; *** α = .01; ****α = .001.

contribution of fare payment to total trip dwell time may be most effective by operating an entry fare policy on local routes with frequent stops and evenly distributed ridership and an exit fare policy on BRT routes with fewer stops and substantial passenger movement at major stops.

Stop-level regression showed a fixed dwell time per stop of 2.6 to 8.6 s per completed stop. Each additional passenger was found to increase dwell time by 4.5 to 5.5 s. Of this time, fare payment contributed 1.0 to 2.9 s per passenger, depending on route type and fare policy. Trip-level regression found a fixed dwell time of 5.29 s per passenger stop and a per-passenger increase in dwell time of 2.74 to 4.82 s, depending on route type and fare policy.

For BRT routes, exit fares were associated with lower per passenger dwell times. When individual stops were considered, BRT routes showed a 0.66-s reduction in dwell time per payment. When total trip dwell time was estimated, BRT routes showed a 1.1-s reduction in per-passenger dwell time under an exit fare policy.

Non-BRT routes, however, showed a different type of impact from exit fares. The statistical model for non-BRT routes yielded either increased dwell times or no statistically significant effect associated with an exit fare policy. At the individual stop level, key corridor Routes 71X and 61X showed respective marginal increases of 0.44 and 0.31 s per passenger payment associated with an exit fare policy. Trip-level analysis predicted local routes to have an increased dwell time of 0.66 s per passenger under an exit fare policy.

These results imply that an exit fare policy may be beneficial for rapid transit routes but unlikely to benefit local or key corridor routes, perhaps owing to the ridership pattern for those routes. Compared with an entry fare policy, exit fares tend to reduce per passenger dwell time when boarding or alighting passengers are concentrated at several major stops, as provided by the fare rules in the Pittsburgh region. The impact of an exit fare policy on the dwell time on local and key corridor routes where the ridership pattern is somewhere between that of local routes and BRT routes is therefore not affirmative.

PAAC will discontinue its alternating fare policy and implement a full-time entry fare policy as of January 1, 2017, having found that rider complaints arising from the complexity of the alternating fare system outweigh the benefits of providing a free ridership zone within the CBD. The findings of this paper suggest that PAAC will see an overall increase in dwell time and trip duration on BRT routes and an overall decrease in dwell times and trip duration on other routes. It remains for a future researcher to validate these findings by comparing dwell times before and after PAAC's fare policy change.

These findings would be improved by validation with another public transit system. Additionally, the robustness of the findings would be improved by the incorporation of farebox data to control for the dwell time variance introduced by cash fare payments and wheelchair ramp usage. Future work may also compare the fare policy impact on dwell times between crowded conditions and uncrowded conditions.

Given the ability of fare policy to alter the timing of when, relative to a trip's progress, fare-payment-associated dwell time is incurred, additional research into other operational impacts of fare policy—especially the incidence of bunching—is warranted.

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