Effects of Fare Collection Policy on Operating Characteristics of a Brisbane Busway Station

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1 ABSTRACT

Transit agencies across the world are increasingly shifting their fare collection mechanisms towards fully automated systems like the smart card. One of the objectives in implementing such a system is to reduce the boarding time per passenger and hence reduce the overall dwell time for the buses at the bus stops/bus rapid transit (BRT) stations. TransLink, the transit authority responsible for public transport management in South East Queensland, has introduced 'GoCard' technology using the Cubic platform for fare collection on its public transport system. In addition to this, three inner city BRT stations on South East Busway spine are operating as pre-paid platforms during evening peak time. This paper evaluates the effects of these multiple policy measures on operation of study busway station. The comparison between pre and post policy scenarios suggests that though boarding time per passenger has decreased, while the alighting time per passenger has increased slightly. However, there is a substantial reduction in operating efficiency was observed at the station.

Keywords: Fare collection, Smart Card, Busway, Bus Rapid Transit, Dwell time, Transit

2 BACKGROUND

Bus dwell time at a station can be influenced by many factors. Although the passenger demand is the major factor, the amount of time required by a passenger to complete the financial transaction to board the bus governs the boarding time per passenger and therefore the bus entry door capacity. The effects of the fare collection system are well documented throughout the literature. Guenthner and Hamat (1988) evaluated the passenger service time against the onboard fare collection system. Marshall et al. (1990) studied the effect of multiple methods of fare collection. The study suggested 8 seconds service time per passenger under complex fare structure. Similarly, Zografos and Levinson (1986) studied the reduction in dwell time under no on-board ticket purchase policy. In a recent study, Milkovits (2008) showed that with 100 percent used of smart card fare medium it could be possible to reduce bus dwell time by 22.8%.

Smart card technology for fare collection is rapidly gaining popularity around the world. The main advantage of implementing such technology is the possibility of an integrated fare system and improved passenger service times at stations and stops (Cheng, 2004). Recently, TransLink, the transit authority responsible for South East Queensland, has introduced Cubic's smart card platform branded as 'GoCard' for fare collection on its public transport services (on board buses and ferries, and at rail stations). In addition to this, three inner city busway stations on South East Busway are operating as pre-paid platforms during evening peak time. To assess the effect of these changes in fare collection system, analysis was conducted to observe the changes in the boarding time per passenger at the Mater Hill Busway station, Brisbane, Australia. This paper presents the results of this analysis and compares them with the pre policy fare system results.

One of the earliest studies towards the understanding of bus dwell time was published by Levinson (1983). He used the simple regression approach to analyse and predict the bus dwell time for the bus stops in across the US cities (Equation 1), Where, *N* is the sum of boarding and alighting passengers at the stop.

$$DwellTime = 5.0 + 2.75N$$ **Equation 1**

During the same period Guenthner and Sinha (1983) in their study on the bus service found that each boarding or alighting passenger contributes 3 to 5 seconds towards the total dwell time of the bus at the stop. From these earlier single variable dwell time models, research started to look at dwell time as a multi-variable model. This approach considered the number of alighting passengers and number of boarding passengers as two separate variables. Vuchic (2005) related dwell time to the function of the number of boarding and alighting passengers plus a constant which accounts for the time taken by the bus to perform the door opening and closing manoeuvre. An identical equation was suggested by the Transit Capacity and Quality of Service Manual (TCQSM) (Kittelson and Associates, Inc) in 1999 and subsequently in 2003 (Equation 2).

$$t_d = P_a t_a + P_b t_b + t_{oc}$$ **Equation 2**

Where,

t_d = Average dwell times (s)

P_a = Alighting passengers per bus through the busiest door (p)

t_a = Alighting passenger service time (s/p)

P_b = Boarding passengers per bus through the busiest door (p)

t_b = Boarding passenger service time (s/p)

t_{oc} = Door opening and closing times (s)

3 METHODOLOGY

Many parameters related to analysis period, study area and observational variables have been considered while conducting this study. The following text illustrates those details.

3.1 Analysis period characteristics

It is essential to consider the correct period for analysis as a transport system's performance varies from time to time on any given day. The flows of passengers and buses vary from lean during the off-peak time to heavy during the peak time. The characteristics of the South East Busway corridor in Brisbane, Australia are such that, during the morning peak, flow of passengers towards city is high, contributing to high numbers of passengers alighting on the inbound platforms of inner stations. This situation is reversed during the afternoon and evening peaks, when there are more boarding passengers on the outbound platforms of the inner stations. Hence, in this study it was necessary to collect appropriate data to study the effects of fare policy. A 30 minute period during the afternoon peak time was adopted for data collection. During this period, the alighting passenger flow is relatively small compared to the boarding passenger flow. This situation provides a better scenario to quantify the affect on boarding times of the fare system. Additionally, during the afternoon peak, the purchasing of tickets on board is now prohibited as a "pre-paid", or platform ticket purchasing, policy is implemented.

Because of the large number of passengers and bus flows at the subject station during the study time, the data collection method was decided with care. On site manual counting can prove to be very laborious and may be susceptible to high human error. As a consequence, video footage of the station platform was recorded and followed by laboratory counting to eliminate human errors as far as possible.

3.2 Data collection

The purpose of data collection was to capture the all the activities occurring at the platform area through video recording and later extracting the key attributes explaining the flow of boarding and alighting passenger through the bus door/s. The aim of the observation was to gather evidence of how the new fare collection policy and bus management measures affected the dwell time of buses. For measuring bus dwell time, the guidelines from Transit Capacity and Quality of Service Manual (TCQSM) (Kittelson, 2003) were followed –

1. Record the bus route number and bay number on which it is serving passenger (s).
2. Record the time at which the bus comes to a complete halt.
3. Record the time of full opening of the bus front door.
4. Count the number of alighting passengers separately from the front and rear door and number of boarding passenger onto the front door.
5. Record the timing for first and last passenger alighting.
6. Record the timing for first and last passenger boarding.
7. Record the time of full closing of the bus front door.
8. Record the time when bus left the bay.

4 DATA ANALYSIS

Three distinct sets of video recordings were collected at the outbound platform of the Mater Hill Busway station between 3:00PM and 3:30PM on the typical weekday of Wednesday. These recordings were collected in March 2007, March 2008 and April 2009. From Brisbane City, Mater Hill station is the third busway station along the 16km long South East Busway corridor as shown in Figure 1. Mater Hill Busway station has three marked loading areas as shown in Figure 2. Very occasionally some buses stop very close to the dwelling bus in front, thereby creating a temporary fourth loading area. The patronage to the station during the analysis periods comprised university students, hospital visitors, workers, and other members of the general public.

The details of recordings and fare policies on the recoding days are given in Table 1. During the annual analysis periods over the three years of the study, four means or combinations thereof were available for passengers to validate their journey. These included manual means, being onboard ticket purchase from the bus operator or presentation of a pre-paid paper ticket. The earlier of two automated means was the use of the 10 trip saver ticket, a magnetic stripe card dipped on entry into one of two readers located inside of the front door only. The later of two automated means was the, use of the GoCard smart card, with each bus equipped with four readers; two readers inside the front door for touch-on and touch-off, and two readers inside the rear door for touch-off only. In 2009 TransLink introduced the pre-paid platform policy for the outbound platforms of three innermost busway stations on the Southeast busway network. Under this policy, during the busy outbound mid afternoon to evening peak period, all passengers must have a pre-paid ticket or a GoCard to enter the outbound platform of each of the Culture Centre, South Back, and Mater Hill Busway stations, as no on board ticket purchasing is permitted. The rationale being to minimise bus dwell times and therefore improve bus capacity and reduce delays.

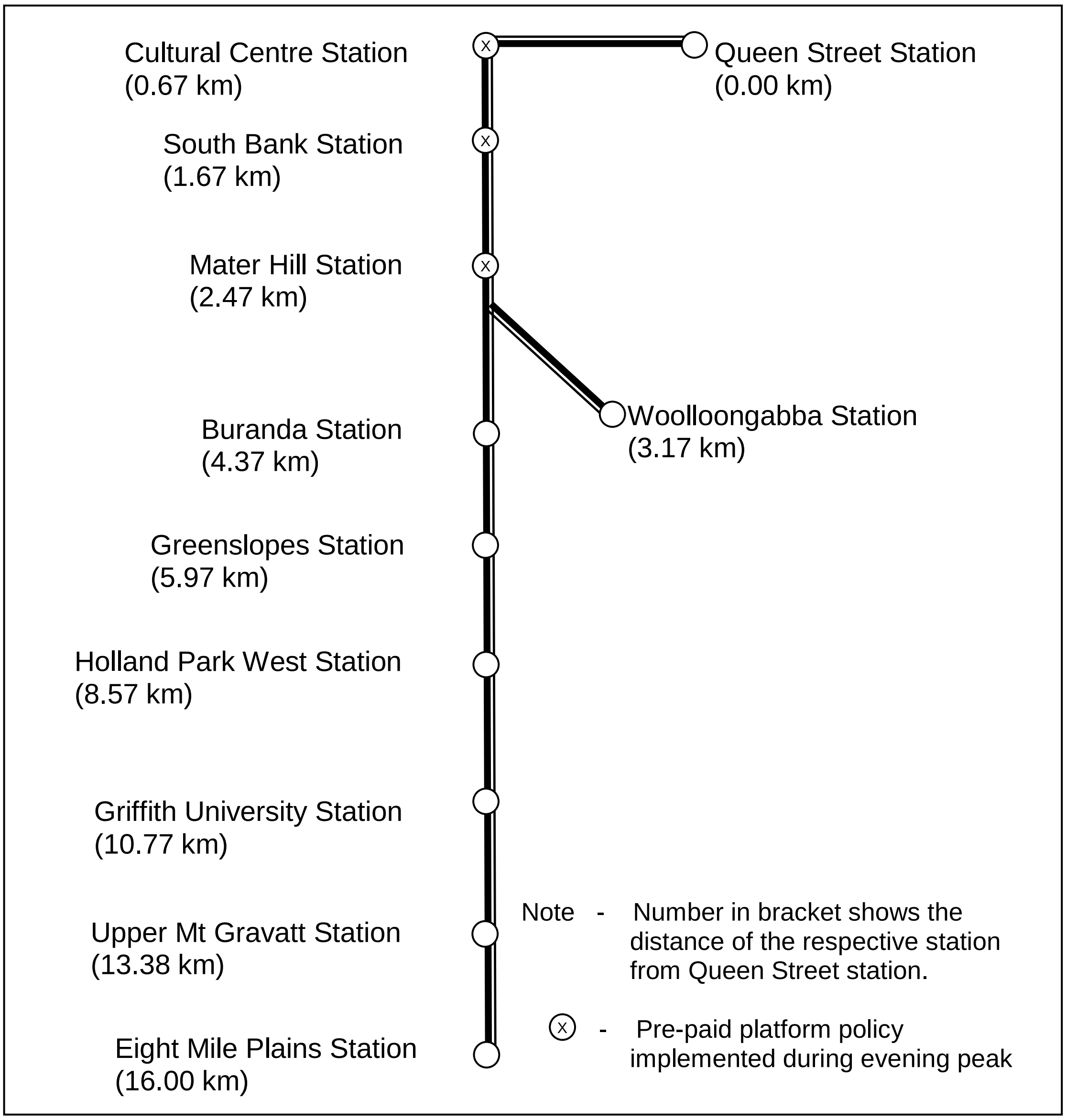

Figure 1 South East Busway route map

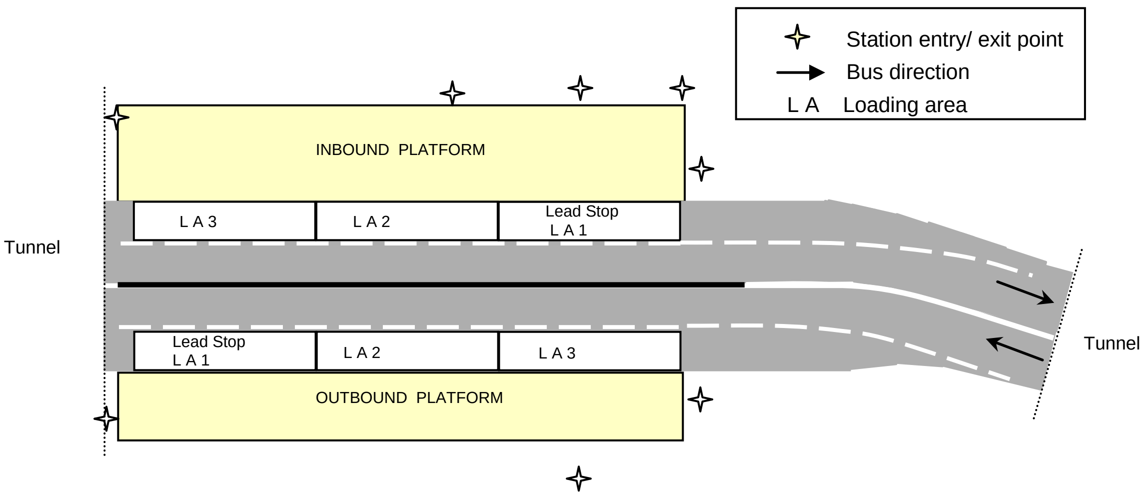

Figure 2 Configuration of Mater Hill Busway station

Table 1: Fare collection policies and observations at study station

Month/ Year	March 2007	March 2008	April 2009
Time Period	Evening Peak	Evening Peak	Evening Peak
Analysis time	3:00PM to 3:30PM	3:00PM to 3:30PM	3:00PM to 3:30PM
Fare policy	On board ticket purchase Pre-paid ticket 10 trip magnetic stripe card into front door dip readers	On board ticket purchase Pre-paid ticket 10 trip magnetic strip card into front door dip readers (Phasing out) GoCard smart card with onboard touch on using readers front door only & touch off using readers at front and rear doors (Introduced)	On board ticket purchase not permitted Pre-paid ticket GoCard smart card with onboard touch on using readers front door only & touch off using readers at front and rear doors Pre-paid platform policy
# of buses	51	36	62
# of boarding passengers	348	475	250
# of alighting passengers	21	17	53

To understand how the changes in fare policy have affected the dwell times of the buses, the study station video recordings were analysed. The behaviour of passengers on the platform were not influenced by the video recording as footage was collected from the permanent busway security cameras mounted on the ceiling of the busway platform awnings. These cameras record platform activity on a 24hr/7 day basis.

Buses were categorized on the basis of the loading area on which they served the waiting passenger/s at the platform. Additionally, bus type and floor type for each bus was recorded. The descriptive statistics of boarding time and alighting time are provided in Table 2

Table 2: Descriptive statistics

	Minimum	Maximum	Average	Std. deviation
For Loading Area 1				
Boarding time per pax	2.5s	6.5s	4.2s	2.5s
Alighting time per pax	2.6s	8.0s	3.4s	1.4s
For Loading Area 2				
Boarding time per pax	3.0s	7.5s	5.0s	2.3s
Alighting time per pax	3.5s	5.0s	4.0s	0.6s
For Loading Area 3				
Boarding time per pax	1.9s	8.0s	4.9s	4.8s
Alighting time per pax	2.0s	6.0s	3.6s	1.4s

4.1 Passenger boarding time

On boarding the desired bus, each passenger is required to touch their GoCard on one of two card readers at the front door before proceeding down the aisle of the bus. At the card reader it is required to ensure that the card is placed at less than 10 cm from reader for 1 or more seconds. This procedure could affect the service time per boarding passenger. The results from March 2007 data (Jaiswal et al., 2007) were compared with the post policy intervention data of April 2009 to gauge the policy intervention effects. Table 3 gives the observed boarding time per passenger across all loading areas of the study station platform for these two periods and the March 2008 transition period. Data from the transition period showed the initial increase in average boarding times for all loading areas. However, later the average boarding time decreased for all loading areas. The initial increase in service time could be attributed to the inexperience of users in using GoCard and/or the mixture of the Magstripe, GoCard and operator as cashier systems in place.

The result highlighted that with removal of on board ticket purchase, there is an increased uniformity in service time per boarding passenger among the three loading areas on the study station platform. The boarding time was decreased by about 15% for loading area 1 and loading area 2 and about 40% for loading area 3.

Table 3: Effect of fare collection policy on passenger boarding time Weekday 3p.m. to 3:30p.m.

Loading area	March 2007	March 2008	2008 change from 2007	April 2009	2009 change from 2007
1	4.8s	6.8s	+42%	4.2s	-14%
2	5.9s	6.0s	+2%	5.0s	-15%
3	8.1s	8.9s	+10%	4.9s	-40%

4.2 Passenger alighting time

The passengers using GoCard are required to touch off their cards to a card reader before alighting from bus to facilitate the accurate fare calculation for their trip. All other passengers are not required to transact at the time of alighting from the bus. Similar to touch on while boarding, touch off also requires passengers to place the card less than 10 cm distance from the card reader and steady for one or more seconds. This inevitably has led to an increase in alighting time per passenger, over the previous system used in 2007 where magstripe card holders were not required to transact on alighting from the bus. Table 4 gives the average alighting time per passenger observed at the study station for the three analysis periods.

Table 4: Effect of fare collection policy on passenger alighting time Weekday 3p.m. to 3:30p.m.

Loading area	March 2007	March 2008	2008 change from 2007	April 2009	2009 change from 2007
1	2.2s	2.0s	-9%	3.4s	+55%
2	1.9s	2.0s	+5%	4.0s	+110%
3	2.1s	2.1s	0%	3.6s	+71%

Alighting times were also found to be affected by the bus type – standard bus and articulated bus. Passengers alighting from an articulated bus at the study station showed a tendency towards using front door of the bus. This behaviour increases the boarding time for such buses. As there were still few articulated buses used on the study platform during this study, no statistically significant results could be produced. The highest increases in alighting time were observed for loading area 2 (110%) followed by loading area 3 (71%) and loading area 1 (55%).

Depending on the door used by alighting passenger/s the alighting time varies in its impact on bus dwell time. Often when parallel boarding and alighting happens through front and rear door respectively the boarding time governs the dwell time. However, when alighting happens from front door, which is also the only designated door for boarding, the alighting time is additive to bus dwell time.

4.3 Loading area and bus dwell time

Table 5 shows the variation of bus dwell times with the loading area of the study station platform. Due to the analysis period being a peak period, all three loading areas were in use by buses to provide service to waiting passengers at the platform. It was found that between 2007 and 2009 the dwell times for the buses at all loading areas reduced. The maximum reduction occurred for loading area 2 whereas loading area 1 had the lowest but still a significant reduction in dwell time. However, this must be tempered against the number of boarding passengers reducing by 28%. The reduction in dwell time on all loading areas is expected to be an outcome of both a reduction in boarding service time per passenger due to the policy decisions discussed previously, as well as a marked reduction in passenger demand on the platform. With the 3p.m. to 3:30p.m. study period being an afternoon school peak period, it is postulated that one or both of the two local private schools may have changed their release times between 2007 and 2009, leading to the significant reduction in boarding passengers, or alternatively there may have been a school event or student free period coinciding with the 2009 study period leading to the reduction.

Table 5 Bus dwell times at Mater Hill Busway Station between 2007 and 2009

	Average Bus Dwell Time			Number of boarding Passengers
	Loading Area 1	Loading Area 2	Loading Area 3	
March 2007	44s	60	55s	348
April 2009	26s	23s	25s	250
% change between 2007 and 2009	-41%	-62%	-55%	-28%

4.4 Loading area occupancy and blocking

Mater Hill Busway station reaches its ideal bus capacity when all three loading areas are occupied by buses. With decreases in dwell times the loading area occupancy rates decrease. However, as buses use the loading areas on a first come first in basis, the station reaches a non-ideal capacity when one or both of the loading area 1 and 2 are empty because a preceding loading area is occupied. The analysis of data showed that, as the occupancy rate has decreased, the blocking of loading areas 2 has risen by three quarter times. Loading area 3 cannot experience blocking since it does not have any predecessor loading area. Table 6 shows the occupancy rate and blocking rate for each loading area during the half hour (1800 s) analysis time period.

Table 6: Occupancy and loading rates for loading areas

Loading area	Occupied Time		Blocked Time		change between 2007 and 2009	
	2007	2009	2007	2009	Occupancy	Blocking
1	790s	697s	372s	128s	-12%	-66%
2	958s	393s	82s	143s	-59%	+74%
3	915s	349s	0s	0s	-62%	NA

Under a perfectly ideal situation each loading area of the station platform should operate without interfering others operation. However in a linear arrangement of loading areas this may not be the case, particularly during the peak period operation when the bus flow is high. Every loading area can potentially obstruct the entry to the successive loading area/s and obstruct exit from immediate predeceasing one. This reduces the number of effective loading areas for the station (TCQSM, 2003) (Kittelson and Associates, Inc). At Mater Hill busway station (Figure 2**) entry to loading area 1 can get blocked by loading area 2 or loading area 3 or both. Similarly, loading area 2 can be blocked by loading area 3. Similarly, exit from loading area 2 and 3 could be blocked by loading area 1 and 2 respectively.**

Table 7 gives the efficiencies of each loading area at study station. The methodology for loading area efficiency calculation presented in Jaiswal et al. 2007 was used. The efficiency equations are

For loading area 2

$$E_{LA2} = \frac{T_3 - T_{2,b}}{T_3}$$ **Equation 3**

For loading area 1

$$E_{LA1} = \frac{T_{2,3} - T_{1,b}}{T_{2,3}}$$ **Equation 4**

Where,

E_{LA2}	=	Efficiency of loading area 2
T_3	=	Total time that loading area 3 is occupied during time T
$T_{2,b}$	=	Total time that the loading area 2 was empty while a bus occupied loading area 3 during time T
T	=	analysis period
E_{LA1}	=	Efficiency of loading area 1
$T_{2,3}$	=	Total time that loading area 2 OR loading area 3 OR loading areas 2 and 3 are occupied during time T
$T_{1,b}$	=	Total time that loading area 1 was empty while a bus occupied loading area 2 OR loading area 3 OR both loading areas 2 and 3

Table 7 Loading area efficiencies

loading area	Loading area efficiency		change between 2007 and 2009
	March 2007	April 2009	
1	0.71	0.77	9%
2	0.90	0.59	-34%
3	1.00	1.00	NA
Total effective loading area	2.61	2.36	-9.6%

The above table clearly shows that efficiency of the loading area 1 have increased by 9%. However, this increase was offset by a more substantial decrease in efficiency for loading area 2. This ultimately led to a net loss of 9.6% in total number of effective loading area compared to the March 2007 data. The movements in efficiencies for loading areas are consistent with the changes in their blocking. This indicates that even though the loading area availabilities have increased, the approachability to these loading areas is hindered due to the inter-loading area blocking, resulting in reduced efficiency.

5 CONCLUSIONS

Passenger boarding times constitute the major portion of bus dwelling time at BRT stations. Identifying the impact of fare collection system on passenger service time is therefore crucial. The effects of the smart card system and pre-paid platform policy were examined and compared with the pre policy intervention scenario of March 2007. Furthermore, the change in total effective number of loading areas was examined.

The analysis highlighted that boarding time per passenger was reduced by a minimum of 14%. However, the alighting time per passenger increased in excess of 50%. However, more investigation required to access the impact of smart card on alighting passengers, specially, for a period when alighting passengers are predominant, such as the morning peak on inbound platforms of inner urban (destination) stations. The average service time for each boarding passenger was 4.7s and for each alighting passenger 3.6 s.

The reduction in total effective loading areas is largely due to a reduction of effectiveness of loading area 2. In order to improve bus dwell time efficiency it is necessary to minimise the amount of time wasted by buses at the station platform. With improvement in the fare collection mechanism bus dwell time can be improved. However, as observed in this study, the advantages of reduced dwell time could be limited due to the blocking of loading areas. A proper understanding of the blocking phenomenon at the busway station is therefore crucial. This area needs further investigation.

Following conclusions were drawn from this study –

- The removal of on board ticket purchasing reduced passenger service time and bus dwell time.
- On the positive side use of smart card fare system decreased boarding time per passenger. On the contrary, the system increased alighting time per passenger.

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