Impact of Slow Zones on CTA Passengers

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Abstract: Infrastructure maintenance projects are becoming common as the Chicago Transit Authority (CTA) system ages and its tracks deteriorate. Due to potentially unsafe track conditions, slow zones are created in areas where CTA trains operate at lower speeds over the tracks to maintain safe travel. Slow zones are also sometimes established temporarily in work zones over a period of ongoing construction work. The elimination of slow zones is becoming increasingly important for the CTA as they plan to retain and attract more customers. While work to upgrade tracks aims for a faster and more reliable service, delays and schedule disruptions due to slow zones are likely to extend passengers' travel and waiting times. Little is known about the relationship between rail slow zones and rail ridership. However, the literature shows that passengers are sensitive to the consequences associated with travel time variability, such as prolonged waiting times at the station, missed connections and arrival times before or after the desired time. As a result, customers experience increased levels of dissatisfaction with the service and may decide to stop using the service for some time, or even permanently. As a consequence a decrease in demand can be expected. This paper aims at understanding the impact of delay caused by slow zones, and also the impact of waiting time at the station, on the CTA blue line ridership. Data collected from Slow Zone Maps and Automatic Fare Collection System (AFC) were used to evaluate these relationships. The findings suggest that slow zones reduce ridership by directly increasing the travel time as train speed decreases and indirectly by increasing the waiting time at the station.

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Introduction

The Chicago Transit Authority operates an extensive heavy rail rapid transit system, which is the second largest in the United States. Most of the system is old, and the oldest structures have experienced more than one hundred years of continual use. Due to potentially unsafe track conditions, slow zones are created in areas where CTA trains operate at lower speeds over the tracks to maintain safe travel. Slow zones are also sometimes established temporarily in work zones over a period of ongoing construction work. While work to upgrade tracks aims for a faster, safer, and more reliable service, passengers are exposed to delays and schedule disruptions due to slow zones extending their travel and waiting times. Almost every line suffers slow zones, which affect even peak-hour service. The elimination of slow zones is becoming increasingly important for the CTA as it plans to retain and attract more customers.

Slow zones may have a significant impact on passengers' satisfaction motivating them to discontinue the use of public transportation for some time, or even permanently. Research has shown that repeated delays and service disruptions indeed generate dissatisfaction with the service and decrease ridership (Andreassen, 1995). However, there are only a few studies that discuss the implications of slow zones on rail ridership. The purpose of this paper is to help closing this knowledge gap.

Given that the Chicago Transit Authority (CTA) relies greatly on fare box revenues, it is important for CTA to better understand the effects of slow zones on ridership in order to avoid potential losses of passengers seeking out transportation alternatives such as shuttle service, ride sharing, or driving when feasible. In a city where automobile dependence is high, it is critical that CTA presents itself as a viable and competitive alternative for transportation.

This paper aims at understanding the impact of delay caused by slow zones, and also the impact of waiting time at the station, on the CTA blue line ridership. It specifically tries to answer the following questions: (1) Do recurring delays due to slow zones affect rail ridership? (2) What is the relationship between ridership and headway, number of trains, and gas prices? (3) Do delays affect passengers with different trip purposes in the same way?

Literature and Hypotheses

Ridership. Many studies of travel choice behavior have found that reliability, punctuality and dependability of a transportation system are very important for passengers. These factors affect riders' perceptions and their level of use of the different transportation modes (Bates et al., 2001). Passengers place high value in having consistent and predictable services. Bates et al., (2001), proposed two explanations for this: (1) travelers are sensitive to the consequences associated with travel time variability, such as prolonged waiting times, missed connections and arrival times before or after the desired time; and (2) travelers place a level of value on the uncertainty induced by variability that is independent of its outcome, perhaps as a result of anxiety or stress, or the added cognitive burden involved with planning activities and travel in uncertain conditions.

Bonsall (2001, 2004) observed that any journey is generally subject to some degree of variability and uncertainty, much of which cannot be controlled by the traveler. The author observed three strategies travelers may adopt when dealing with uncertainty: trying other modes of transportation; deliberately avoiding certain modes, routes, and times that are prone to disruption or variability; or abandon the journey if conditions do not allow it to be completed.

Friman and Garling (2001) argue that delays in public transportation are likely to extend waiting time generating uncertainty for the overall trip which creates frustration and dissatisfaction with the service.

According to Preston et al. (2009), train delays can come from three sources: operator causes (e.g. train faults and shortage of crew), external causes (e.g. extreme weather) and, infrastructure causes (e.g. track and signaling faults). Defective track, signaling and structure faults can be caused by wear and tear on an aging structure. As the rail system ages, these components cannot be successfully maintained and require complete replacements.

In the case of CTA, some sections of structure have already served for over a century (Abrams, 1998). As the condition of the CTA infrastructure continues to worsen, speed restrictions have to be imposed on potentially unsafe lengths of track. In an attempt to reverse this trend, aging structures must be repaired. Because service on rapid transit operation is both, frequent and continuous, the creation of slow zones is necessary while repair work is on its way. Schedules are thus affected, providing a service no longer rapid.

Major reconstruction projects require numerous slow zones making travel times for passengers significantly lengthened. Abrams (1998) mentions that the prolonged presence of slow zones may have long-term negative effects on passengers, and unless reconstruction can be accomplished without seriously inconveniencing them, ridership will suffer, even for a long time after the project is completed. For most people, commuting is a daily routine and, once that routine is interrupted, a commuter will find another means of transportation on either a permanent or a temporary basis.

The literature described above lead us to hypothesis that:

H1: Rail ridership will decrease as delays due to slow zones increase.

Fare Type. The Chicago Transit Authority has been offering Smart Cards since 2002, and has been collecting and storing the data from the scanned transactions of this medium. Smart Cards[1] are plastic cards with an embedded microchip that can be read by a panel on rail turnstiles and bus fareboxes. They offer customers the added conveniences of "touch and go" access and a more durable plastic card that would not lose its remaining value even if it gets lost. Smart Cards make the boarding easier and faster, helping improving travel time for all customers (Yi, 2006). Thus, frequent users, such as commuters, are more likely to use Smart Cards because of the cost savings and their

[1] TRCP 94, Fare Policies, Structures and Technologies: Update, 2003.

convenience[2]. Indeed, Oram and Stark, (1996) show that fare prepayments (e.g. smart cards) correlates with more riding, trip rate stability, and longer duration as a rider. On the other hand, infrequent riders, new riders, and riders with changing trip rates tend to pay in cash.

Differences between perceptions of delay of frequent and infrequent passengers may be significant. Preston et al. (2009) argues that infrequent travelers base their view on their most recent journey or even on reports in the press, while frequent riders may not.

Bonsall (2004) discuss that the trip purpose determines the importance of the accuracy of the arrival and departure time. When the time accuracy is not crucial to the customer, a delay does not create the same level of anxiety and resulting dissatisfaction, as it would for the customer facing time constraints. Assuming that Smart Card users tend to have a different and more defined trip purpose and time accuracy may be more important than that of non-Smart Card users, we expect that the effect of slow zones will be higher on smart card users compare to non-smart cards.

H2: Smart Card ridership will be more affected than non-Smart Card ridership by slow zones.

Headway. The headway is the time interval between departures. Higgins (2000) states that for frequent service [like the CTA], passengers may not plan to use a specific departure, they just arrive at their chosen time in order to catch the next departure and they might arrive at any time between two departures. Their waiting time at the station can be zero if they arrive just in time for a departure; they may also arrive immediately after a departure and have to wait for a length of time equal to the headway. The waiting time at the station follows a uniform distribution ranging from zero to the headway (Ling and Taylor, 1988; Kikuchi, 1985). Therefore, headway could be a proxy measure for passenger waiting time and because travelers are sensitive to prolonged waiting times,

[2] CTA's Customer Experience Survey, 2008

ridership may be affect due to increased dissatisfaction with the service (Bates et al., 2001).

Frequency of service is directly related to the number of passengers using the route. Headway depends on the amount of trains in the line and the delays (Kikuchi, 1985). A shorter headway signifies a more frequent service, and frequent service is directly related to the number of passengers using the service (Warren, 1997).

Metro systems operate with headways typically in the order of 1 to 5 min. Headway has an important impact on ridership levels above a certain critical waiting time (Boyle, 2006). This suggests that the relationship between headway and ridership involves a threshold. The literature of headway discusses the effect of "knock-on" delays on trains. Any delay to one train in a peak period may cause "knock-on" delays to following scheduled trains (Carey et al., 1994; Higgins and Kozan, 2000). Knock-on delay refers to that part of train's delay that is caused by other trains in front of it (Higgins and Kozan, 2000). The shorter the schedule headway between trains, the greater is the expected knock-on delay and hence the expected trip times of following trains. Delays to following trains also depend on train control and signaling system, required minimum headway between trains, and speed restrictions of following trains. Therefore, we expect that delays due to slow zones affect headway. The following hypotheses are derived from the discussed literature:

H3: Ridership will decrease with longer headways.

H4: Ridership will decrease as the number of trains on track decreases.

H5: Headway will increase as delay due to slow zone increases.

Gas prices. A series of geopolitical events, market forces, and countless other catalysts have driven fuel prices skyward between 2004 and 2008 (Maley and Weinberger, 2009). Over 2008, people took more public transit trips than in any year since the U.S congress passed the Federal-Aid Highway Act in 1956 (Cooper, 2009). Studies and articles noted declines in sport utility vehicle purchases and vacation travel, whereas they highlighted surges in hybrid car purchases and transit ridership (Korkki, 2008). Indeed, at least some commuters have changed their travel habits and rely on transit to lighten the burden to their wallets. According to Haire and Machemehl (2007), higher fuel prices have driven ridership growth to many transit agencies. Past research has demonstrated a statistically significant relationship between increases in the price of gas and increases in transit ridership (Currie and Phung, 2007; Haire and Machemehl, 2007; Wang and Skinner, 1984; Semmens, 2007). Other findings indicate that fuel price increases have also played a role in encouraging transit use in historically automobile-oriented U.S cities.

With the big variations that have been observed over the last couple of years in gas prices and the effect that this has had on people's budget it would not be surprising to find that there is a positive relationship between gas prices and rail ridership. The hypothesis is as follows:

H6: Rail ridership will increase as gas prices increase.

Data and Models

We tested the hypotheses using data from Automatic Fare Collection (AFC) System, Rail Slow Zone Maps of the Blue Line (see Appendix A), CTA's Actual and Scheduled Headway Data, OD Directional data (Origin – Destination), and Chicago Gas Prices Data.

The Automatic Fare Collection System (AFC) records all the transactions in rail stations and buses and produces a detailed list of all daily boarding. In the case of the rail system, the stations turnstiles are continuously sending data to a central server. AFC also reports the type of transaction made by the passenger. The fare media type options that passenger have are cash (only on buses), magnetic cards, magnetic passes, and smart cards. Only with smart cards, the system keeps track of the individual ID of each card.

The Rail Slow Zones Maps show the areas where trains are required to operate at slower than normal speeds due to track conditions and to maintain safe travel. This occurs in a section of track that is beyond its service life and in need of repair or replacement. Slow zones are also established temporarily in work zones over a period of ongoing construction work.

Dataset. The time series data sample includes ridership, delay due to slow zone, and actual and scheduled headway from the O'Hare branch of the Blue Line which includes 13 stations from O'Hare to Damen. The time period selected was from September 2007 to April 2009. The CTA keeps track of ongoing slow zones in its rail system thorough the creation of maps that shows the speed limits of different sections of the tracks. The Slow Zones Maps are published every time there is a change in the slow zones. The time period selected comprises most of the Rail Slow Zone Maps records available at the time of the analysis. A few more records are available in 2006 but they are too spread across the year. Each Rail Slow Zone Map corresponds to a particular day and there are 44 maps for the selected time period. The data from a slow zone map is therefore held forward until the next map. Our dataset contains a total of 430 time observations. The analysis focused only on weekends and the morning peak period (6am - 10am) where demand for the service is at its highest and a reliable service is paramount. Entries for ridership, actual and scheduled headway, and gas prices were selected to correspond to the dates for which slow zone information was available in the Rail Slow Zone Maps. Slow Zone data was aggregated by direction (Northbound and Southbound) and branch (O'Hare). Ridership data by direction was obtained from CTA based on CTA analysis/models. Ridership was aggregated by direction branch, type of fare (Smart Card and Non-Smart Card) and, Peak/Off-Peak periods. Actual and Scheduled Headway data were aggregated by direction, branch and, Peak/Off-Peak periods.

Dependent Variables. The hypotheses were tested using two dependent variables: **Ridership** and **Headway.** Ridership was derived using AFC data which is collected using the farebox. Each customer passing through a rail station turnstile is counted as a single rider. Ridership is calculated as the total number of passengers entering the blue line system at any station of the O'Hare branch. We classified ridership as: total ridership, smart card ridership and, non-smart card ridership. The calculation was made by grouping the ridership by type of fare and then adding them up. In order to estimate ridership by direction we multiplied rider share by direction provided in the OD Directional data.

The second dependent variable, Headway, was derived from the Actual Headway data and indicates the proportion of headway that occurred between zero and one minute. This was calculated by aggregating the total counts of headways in two groups: less than 1 minute, and more or equal to 1 minute.

Independent Variables. **Delay** was measured as the extra time (minutes) a passenger would spend riding a train due to slow zones. Delay was derived from Slow Zones Maps. The slow zone maps have the posted speed for a section of tract, the slow zone speed for that section, and the distance of the section of track. Using these, the indicated travel times and was estimated for each section and then for the line by direction. Delay was calculated as the difference between the indicated actual travel time and the expected travel time. The expected travel time was estimated using the CTA's Trip Planner tool[3]. The variable **Delay Squared** was also included in order to capture non-linearity. **Headway** was also used as an independent variable when predicting ridership. **Number of Trains** was derived from the Scheduled Headway Data. **Gas Prices** matching the selected time period were collected from the U.S Energy Information Administration[4] and is a ratio variable that indicates the Chicago retail gasoline prices in Cents per Gallon.

In order to test our hypotheses, two equations were fitted to the data using multiple regressions. The models for the regression were specified as follows:

(1) Ridership = *f* (*Delay, Delay Squared, Headway, Number of Trains, Gas Prices)*

(2) Headway = *f* (*Delay, Delay Squared, Number of Trains)*

[3] Available at: http://www.transitchicago.com/travel_information/trip_planner.aspx

[4] Source: U.S Energy Information Administration, at: http://www.eia.doe.gov/oil_gas/petroleum/data_publications/wrgp/mogas_history.html

Analysis and Results

Table 1 shows the results of the regressions of model 1. This table shows the effects of *Delay*, *Delay Squared*, *Headway*, *Number of Trains* and *Gas Prices* on *Ridership* of the O'Hare Branch. As expected, during the morning peak and northbound direction, *Delay* has a significant negative impact in *Ridership* (Total, Smart Card and non-Smart Card Ridership), indicating that when delay increases ridership decreases. The effect of delays on ridership is stronger for Smart Card ridership for the northbound direction of the O'Hare branch than for Non-Smart Card ridership. However, the opposite is true for the southbound direction: Non-Smart Card ridership is more affected by delays than Smart-Card ridership. A customer satisfaction survey by the CTA shows that a significant amount (71.6%) of blue line riders is composed of infrequent or occasional users and that among them only between 14.2% and 16% depend on the system[5]. We speculate that a big portion of non-smart card ridership in the southbound direction comes from those infrequent or occasional passengers traveling from the airport to the city. These passengers may decide more easily than regular commuters (a bigger portion of the Smart Card users -38%[6]) to use alternative means of transportation because they do not depend much on the system and may be more willing to pay extra for a taxi or shuttle or even ask somebody from the city to pick them up if they know that the blue line is experiencing long delays due to slow zones. This may explain the bigger effect of *Delay* on Non-Smart Card ridership vs Smart Card for the southbound direction.

The relationship between *Delay Squared* and ridership is not clear. It has a significant effect on *Total and non-Smart Card Ridership* but its effect is positive. On the other hand, *Delay Squared* does not have an effect on *Smart Card*. We included *Delay Squared* in the regression to test for nonlinearities in the relationship between delays due to slow zones and ridership but the results are hard to interpret and may be due to

[5] CTA's Customer Experience Survey, 2008.

[6] CTA's Smart Card Customer Satisfaction Survey, 2007.

multicollinearity between *Delay* and *Delay Squared*. Further research is needed to better understand the non-linearity between delays and ridership.

Headway has a positive and significant effect on ridership, meaning that the shorter the headway (bigger portions of headways less than 1 minute) the higher the ridership. We found a significant effect of *Headway on Total, Smart-card and Non-Smart Card Ridership in the northbound direction* and for *Total* and *Non-Smart Card Ridership* in the southbound direction.

Contrary to the expected, *Number of trains* has no effect on any ridership in the northbound direction, but in the southbound direction, it does have a positive and significant effect only on *Smart Card Ridership*. This may suggests that frequent riders traveling downtown are more sensitive to changes in the number of trains on the tracks, and in that way to the frequency of the service, than riders heading to O'Hare airport.

As expected, *Gas Prices* have a positive and significant effect on *Ridership* indicating that when the price of gasoline increases, ridership increases too. The effect is bigger on Non-Smart Card ridership and this may be explained by the fact that Non-Smart Card passengers are more likely to be infrequent or occasional users and choose to use the system at their convenience if they see opportunities to save money as prices go up. If gas prices go down they may prefer to use their personal cars. Frequent users are more dependent on the system and may not be able to use a car even if gas prices are low.

Table 1. Effects of Delay, Headway, Number of Trains and Gas Prices on Rail Ridership by Type of Fare and Direction: Headway less than 1 min, O'Hare Branch, Morning-Peak (6am-10am).

Northbound

Independent Variable	Total Rail Ridership B	Sig	Smart Card Ridership B	Sig	Non-Smart Card Ridership B	Sig
Constant	4651.838	***	7376.161	***	2328.741	***
Delay	-55.545	***	-72.639	***	-26.005	***
Delay Squared	17.592	***	0.339		15.574	***
%Headway<1	1290.549	***	706.691	**	1172.019	***
Number of Trains	-36.881		-65.975		-56.121	
Gas Prices	4.196	***	2.200	***	3.359	***
R Square	0.416		0.369		0.381	

Southbound

Independent Variable	Total Rail Ridership B	Sig	Smart Card Ridership B	Sig	Non-Smart Card Ridership B	Sig
Constant	15269.744	***	1439.391	***	9080.912	***
Delay	-209.880	***	-13.621	***	-151.657	***
Delay Squared	45.401	***	0.521		47.193	***
%Headway<1	1885.311	**	-47.256		1771.601	***
Number of Trains	-115.432		27.258	**	-133.024	
Gas Prices	8.862	***	0.277	***	7.009	***
R Square	0.342		0.293		0.397	

*** p < .01; ** p < .05; * p < .10

Table 2 shows the results of the regressions of model 2. The relationship between headway and slow zones is shown in this table. As expected, Headway is affected negatively by delays due to slow zones. The bigger the delay the lower the proportion of headways less than 1 minute; this indicates that headway would tend to be larger. This is clear for the northbound direction. For the southbound direction *Delay* does not appear to have a significant effect on *Headway* but *Delay Squared* does. *Number of Trains* only has a significant and positive effect on *Headway* for the southbound direction. The more trains the shorter the Headway.

Table 2. Effects of Delay and Number of Trains on Headway by Direction on O'Hare Branch and Morning-Peak.

	Northbound		Southbound	
Independent Variable	Headway		Headway	
	B	Sig	B	Sig
Constant	0.897	***	0.391	***
Delay	-0.011	***	-0.001	
Delay Squared	-0.002	***	-0.001	***
Number of Trains	-0.006		0.033	***
R Square	0.410		0.207	
*** p < .01; ** p < .05; * p < .10				

Discussion and Conclusions

This study suggests that there is a strong evidence to support most of the hypothesis.

Future research should aim at better understanding the relationship between train station location and its ridership sensitivity to delays in the system.

Based on the results, we can suggest the following two actions for the Chicago Transit Authority:

1) Manage delays to reduce impact: Given that delays have a significant effect on smart cars ridership, CTA should try to avoid having prolonged slow zones as they affect ridership in a greater degree. Probably it would be preferable to have more frequent mild delays than few critical ones, but future research is needed to assess the impact of frequency of delays versus the severity of them.

2) Manage riders' perception with advanced proactive communication: Literature suggests that dissatisfaction with the public transportation service is in great measure due to a mismatch between expectations of the service and the actual service performance. Therefore, managing riders' perceptions and expectations about the service would allow CTA to reduce the level of dissatisfaction preventing users to leave the system either on a temporary or permanent basis. Because Smart Card users are affected in a stronger way by train delays than passengers using other fare type, CTA should device strategies that reinforces and strengthen the ties with these customers. CTA should take advantage of the personal information they have about smart card users to better communicate and interact with them, for example, continually informing them about upcoming delays and new critical events.

In conclusion, this study shows why it is important for CTA and other transit operators to understand the extent to which passengers are affected by delays due to slow zones: so they can adequately manage service to adjust to demand, optimize vehicle use throughout the system, and improve customer satisfaction.

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Appendix A. Sample of a Rail Slow Zone Map