Understanding the Impacts of Delays on Blue Line Customers

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Abstract: The Chicago Transit Authority (CTA) system has been experiencing ongoing delays and stoppages due to recurring incidents such as track reconstruction projects and precautionary slow zones. As a consequence, customers have been exposed to disruptions in the service. The literature on travel behavior has shown that repeated delays and service disruptions generate dissatisfaction with the service which may result in a decrease in demand. Delays and incidents have a significant negative impact on passengers' satisfaction motivating users to discontinue the use of public transportation after having reached a certain point of frustration. Passengers may respond to incidents by changing their perceptions about the reliability of the service, or by changing their location and/or travel behavior on either a permanent or a temporary basis. This research aims to understand the effects of delays on ridership. Data collected from the Automatic Fare Collection (AFC) System and Rail Slow Zone Maps of the Blue Line were used to evaluate this relationship. The results point to a strong correlation between delays and rail ridership, indicating that as customers experienced delays they have decreased their use of the rail system. However, the impact of slow zones in diverting ridership on to the bus is not as evident as would be expected. These results suggest that transit agencies should take an active role in managing delays and consumers' perceptions about the reliability of the service. Understanding the effects of delays in ridership would help CTA to avoid potential loss of customers.

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Introduction

Infrastructure maintenance projects are becoming increasingly important for the Chicago Transit Authority (CTA) as their system ages and experiences the rough freeze and thaw weather cycles that deteriorate their tracks. This causes the CTA trains to operate at lower speeds over the tracks because of potentially unsafe conditions. While CTA maintenance projects aim to improve the service, customers are exposed to delays and schedule disruptions.

The literature on travel behavior has shown that repeated delays and service disruptions generate dissatisfaction with the service that may result in a decrease in demand (Andreassen, 1995). Delays and incidents have a significant impact on passengers' satisfaction motivating users to discontinue the use of public transportation after having reached a certain point of frustration. Passengers may respond to delays and incidents by changing their perceptions about the reliability of the service, or by changing their location and/or travel behavior on either a permanent or a temporary basis.

Given that the Chicago Transit Authority (CTA) relies greatly on fare box revenues, it is important for CTA to better understand the effects of service delays 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 were automobile dependence is high, it is critical that CTA presents itself as a viable and competitive alternative for transportation. This is why it is so important for CTA and other transit operators to understand the extent to which passengers are affected by ongoing delays and significant stoppages: so they can adequately manage service to adjust to demand, reduce operating costs, optimize vehicle use throughout the system, and improve customer satisfaction (Morency et al., 2007).

This research aims to understand the effects of delays on ridership. It specifically tries to answer the following questions: (1) How do recurring delays affect rail and bus ridership? (2) Are rail and bus ridership impacted differently with respect to delays in the rail system? (3) Do delays affect passengers with different trip purposes in the same way?

Literature and Hypotheses

Research on travel behavior is essential to understand the factors that affect passengers' transportation choices, especially during or after unfavorable events such as extreme and ongoing delays resulting from track reconstruction projects, bus route changes, or other incidents.

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. In some cases, passengers place higher value in having consistent and predictable services than in the average time spend traveling. Bates et al.,(2001), found that punctuality is indeed highly valued by rail passengers.

Reliability and uncertainty. Reliability is one of the most important aspects of public transportation service. It has been generally defined as "how often service is provided when promised" (Transit Cooperative Research Program, 2003). Reliability largely affects traveler's time, as it is often related to the possibility of lateness, longer time spent waiting, as well as with the stress associated with uncertainty itself (Bates et al, 2001).

In regards to the importance of reliability in public transport services, Bates et al., (2001), proposed two explanations: (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. Also, reliability impacts total trip time as most passengers must plan to arrive prior to the scheduled departure time to ensure that they do not miss their bus or train, (Transit Cooperative Research Program, 2003). Delays are also likely to extend waiting time and in some cases generate uncertainty for the overall trip.

Bonsall (2004) observed that journeys are generally subject to some degree of variability. Every trip that is made by foot, bicycle, car, bus, train, or plane, involves some degree of uncertainty, much of which cannot be controlled by the traveler. Bonsall (2001, 2004) 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 the journey to be completed.

The described relationship between public transportation users, reliability of the system and the uncertainty of the journey allow us to make the following hypotheses:

H1: Rail ridership will decrease as train delays increase

H2: Bus ridership on routes connecting to rail stations will decrease as train delays 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 won't 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 convenience. Occasional CTA users and tourist would less likely to obtain a Smart Card. It would be fair to assume that Smart Card users tend to have a different and more defined trip purpose than that of non-Smart Card users. Bonsall (2004) argues 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

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

level of anxiety and resulting dissatisfaction, as it would for the customer facing time constraints. Therefore we offer the following hypothesis about the mediating effect of fare type on the relationship between train delay and rail ridership:

> H3: Smart Card rail ridership will decrease more than non-Smart Card rail ridership in response to train delays. .

Severity of delays. Critical incidents are defined as service encounters that are particularly satisfying or dissatisfying (Friman and Garling, 2001). There are various degrees of severity of negative incidents and they can generate different levels of customer dissatisfaction. As Friman et al. (2001) noted, negative critical incidents can have a higher impact on customers' cumulative satisfaction with the service than positive experiences because negative encounters tend to be more significant and stay longer in memory. Their research revealed that a negative relationship exists between the frequency of negative critical incidents and attribute-specific cumulative satisfaction (e.g., travel time, cost, and frequency of service). A Edvardsson's (1998) study in public transportation, revealed that the dominant types of negative critical incidents include punctuality (too early, too late, non-appearance), treatment or conduct by front-line personnel, and poorly designed information. Friman et al. (2001) found that, "avoiding dissatisfaction is likely to be the users' goal in using public transport services." Regarding the source of some of the aforementioned punctuality-related incidents, the main challenge for public transport service providers lies in preventing defects in the coordination of services. Buses and trains may arrive too early, too late, not frequently enough during peak hours, or may not arrive at all as a result of inadequate logistical planning (Edvardsson, 1998). If the severity of the delays is related with the tolerance towards them and their impact is non-linear we can make the following hypothesis about the differential effect of delay severity on rail ridership:

> H4: The rate of decrease in rail ridership will rise as severity of the delay increases.

Transit options. There are certainly other factors that affect the relationship between train delays and rail ridership. For instance, people who depend on the train system and do not have alternative means of transportation around them and will have to stick with the train as their means transportation even if their dissatisfaction level is high. Bus availability around the train stations is one of the factors that determine the dependency on the train system; because areas with few bus stops riders would have less transit choices and would be more likely to stick with the train system, therefore the following hypothesis can be made:

> H5: As bus availability around rail stations increases, the effect of train delays on declining rail ridership will also increase.

Gas prices. An analysis of rail ridership would not be complete if gas prices are not included. 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: Ridership will increase as gas prices increase.

Additionally, people that are more dependent on the system will have fewer options to react to changes in gas prices and will probably keep using the system as usual. Commuters already made a decision that they rather take the train to work than use other transportation modes. Therefore, an increase in gas prices will not necessarily affect their decision of commuters to use the train more frequently. On the other hand, people using the train system for other reasons than commuting may be more sensitive to dramatic increases in gas prices and will be more likely to use the train when prices are up. Therefore another hypothesis is:

H7: Higher gas prices will have a lower impact on Smart Card ridership than on non-Smart Card ridership.

Data and Models

We tested the hypotheses using data from Automatic Fare Collection (AFC) System and Rail Slow Zone Maps of the Blue Line (see Appendix A). The Rail Slow Zones are 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 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.

The Automatic Fare Collection System (AFC) records all the transactions in rail stations and buses and produces a detailed list o all daily boarding. In the case of the rail system, the stations turnstiles are continuously sending data to a central server. In the case of bus fare boxes, the recorded data are downloaded on a daily basis by the driver when the bus enters the depot. AFC also report 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.

Dataset. The data sample includes ridership on the Blue Line branch from O'Hare passing through the Loop until Clinton station from March 2007 to April 2009. This time period was selected because it comprises most of the Rail Slow Zone Maps records. A few more records are available in 2006 but they are too spread across the year. There are 57 records for Rail Slow Zone Maps for that period of time. Those 57 time observations comprise our sample. Entries for ridership were selected to correspond to the dates for which rail delay information is available in the Rail Slow Zone Maps.

Dependent Variables. The hypotheses are tested using two dependent variables: **Rail Ridership** (Blue Line) and **Bus Ridership.** Both dependent variables are derived using AFC data which is collected using the farebox. Each customer boarding a bus or passing through a rail station turnstile is counted as a single rider. Both dependent variables are calculated as the total number of passengers entering the system. For example, the first dependent variable **Rail Ridership** is the sum of passengers entering the blue line system at any station between O'Hare and Clinton. The second dependent variable **Bus Ridership** is calculated as the total of passengers using the bus routes surrounding the blue line stations.

Independent Variables. Because our analysis is focusedon the impact of delays on passengers, we include a number of independent variables about the characteristics of the delays and the passengers. **Delay** was measured as the extra travel time a passenger would spend riding from O'Hare to the Loop. To have a relative measure instead of an absolute number, given that passengers may enter the system at any station between O'Hare and Clinton, the magnitude of the delay is reported as a percentage of the normal travel time. For example, if the extra travel time is 10 minutes, and the normal travel time is 45min from O'Hare to the Loop, the delay will be 22%. (10/45).

An ordinal variable, **Severity of Delay**, indicates the criticality of the delay. It was coded one if the delay is below one standard deviation from the mean, two if the delay is between -1 standard deviation and +1 standard deviation, and coded three if the delay is above one standard deviation from the mean. This variable is calculated taking into account the mean of the delay and the standard deviation around the mean. Thus, as the severity of delay increases the delay is considered an extreme delay. **Gas Prices** is a ratio variable that indicates the Chicago retail gasoline prices in Cents per Gallon.

Type of Fare is a passenger characteristic. We considered as Types of Fare, Smart Cards and Non-Smart Cards. This variable was calculated by grouping the total rail ridership by type of fare and then summing for each group the total number of passengers that use Smart Cards and the total number of passengers that use other type of fare.

Availability of Transit Modes indicates the amount of bus stops within an area of a quarter mile square around each blue line train station. This variable was calculated using

Geographic Information System (GIS) Software in order to link bus stops data to the stations location. The result was a variable that clusters blue line stations in quartiles. The maximum amount of bus stops within the area around a train station is 134. Thus, the first quartile contains the blue line stations that have from 0 to 45 bus stops, the second quartile contains the blue stations that have from 46 to 55 bus stops, the third quartile contains the blue stations that have from 56 to 72 bus stops, and the fourth quartile contains the blue stations that have from 73 to 134 bus stops. Table 1 shows the blue line stations that belong to each quartile.

Table 1. Blue Line Stations by bus stops availability

Blue Line Stations	Number Bus Stops
Quartile 1	
O'Hare	0
Rosemont	0
Cumberland	14
Montrose	37
Harlem	38
Irving Park	45
Addison	45
Quartile 2	
Belmont	52
Chicago	54
Western	55
Damen	55
Quartile 3	
Logan Square	58
California	58
Division	62
Grand	68
Jefferson Park	72
Jackson	91
Quartile 4	
LaSalle	97
Washington	100
Monroe	100
Clark	134

In order to test the hypotheses, four multiple linear regressions were conducted to test hypotheses 1, 3, 6 and 7; a Pearson Product-Moment Correlation to test hypotheses 2 and 5; and a One-Way ANOVA to test hypothesis 4. The models for the regression were specified as follows:

Rail Ridership | Bus Ridership | Smart Card Rail Ridership | Non-Smart Card Rail Ridership = *f* (*Delay, Delay Squared, Gas Prices)*

Analysis and Results

Table 2 shows the results of the four regressions. As expected, *Delay* have a significant negative impact in *Rail Ridership.* Expected as well, *Smart Card Rail Ridership* is more affected by train delays than *Non-Smart Card Rail Ridership,* being the last one non-significant affected. The direction of the relationship between *Smart Card Rail Ridership* and *Delay* is negative and significant at the 0.05 significance level indicating that when the delay increases the ridership decreases.

As hypothesized, *Delay* has a negative effect on *Bus Ridership* at the 0.01 significance level. As train delay increases *Bus Ridership* decreases. A possible explanation of this relationship is that as train delays rise there will be fewer passengers flowing "in" of the rail system using the bus routes that connect with the blue line stations.

Table 2. Effect of Train Delay and Gas Prices on Bus and Rail Ridership by Type of Fare

Independent Variable	Total Rail Ridership		Smart Card Ridership		Non-Smart Card Ridership		Total Bus Ridership	
	B	Sig	B	Sig	B	Sig	B	Sig
Constant	80029.813	***	37341.73	***	42688.0853	***	257403.6	***
Delay	-3513.273656	*	-2815.89	**	-697.38271		-11742.54	***
Gas Prices	49.056	***	0.45		48.605695	***	134.6953	***
R Square	0.164		0.088		0.341		0.381	

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

The relationship between rail and bus ridership is show in Figure 1. As expected, *Rail Ridership* is positive and significantly related with *Bus Ridership.* This indicates that they tend to have the same pattern in response to train delays.

Figure 1. Rail and Bus Ridership relationship

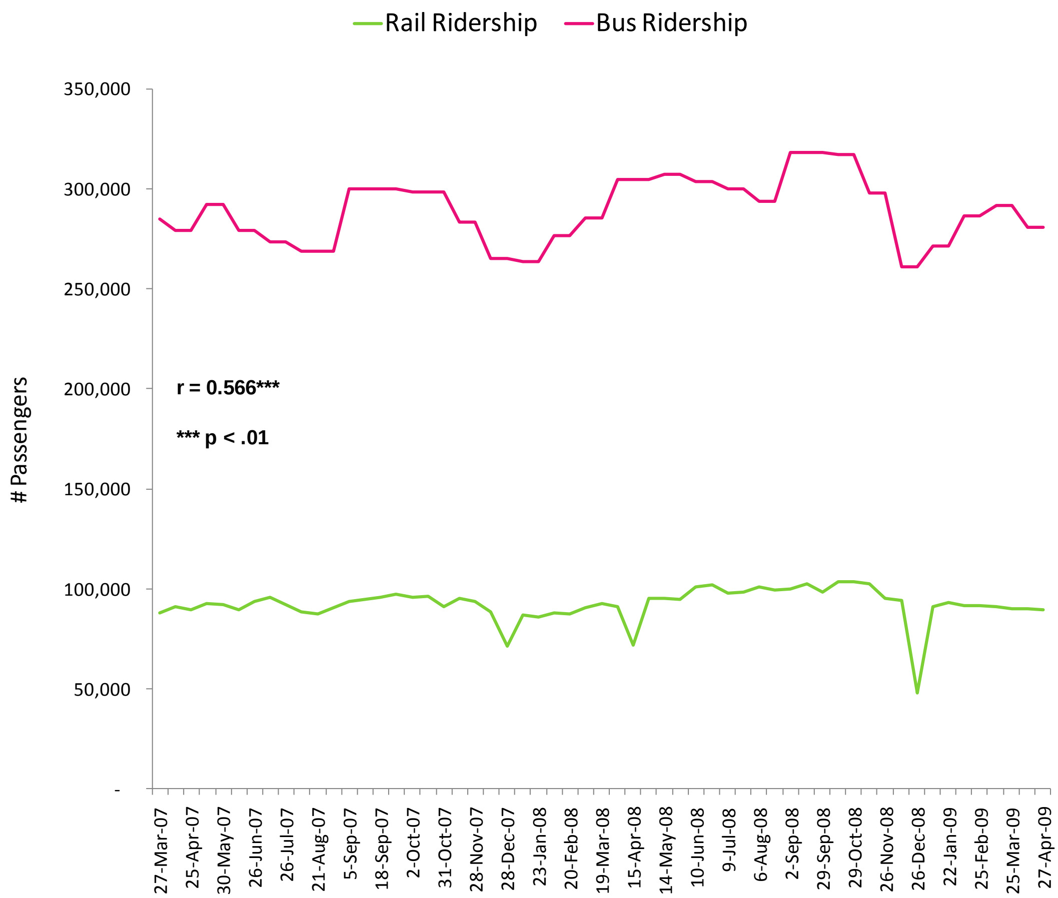


Table 3 and Figure 2 show the results of the ANOVA. As predicted, *Rail Ridership* is affected differently by the *Severity of Delay* but this occurred only for Smart Card ridership: When there is a moderate or critical delay rail ridership is significantly lower than when the delay is mild (below one standard deviation).

Table 3. Delay in the Blue Line and Rail Ridership by Type of Fare and Severity of Delay

Type of Fare	F		Severity of Delay		
			Delay < - 1SD	-1SD < Delay < +1SD	Delay > 1SD
			A	B	C
			Mean	Mean	Mean
Total Rail Ridership	0.211		93254	91499.77	92307.93
Smart Card Ridership	3.459	**	37702.88 BC	34095.85 A	33164.57 A
Non-Smart Card Ridership	1.529		55551.12	57403.92	59143.36

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

Note: Letters indicate significant differences between groups at 0.1 level

Figure 2. Delay in the Blue Line and Rail Ridership by Type of Fare and Severity of Delay

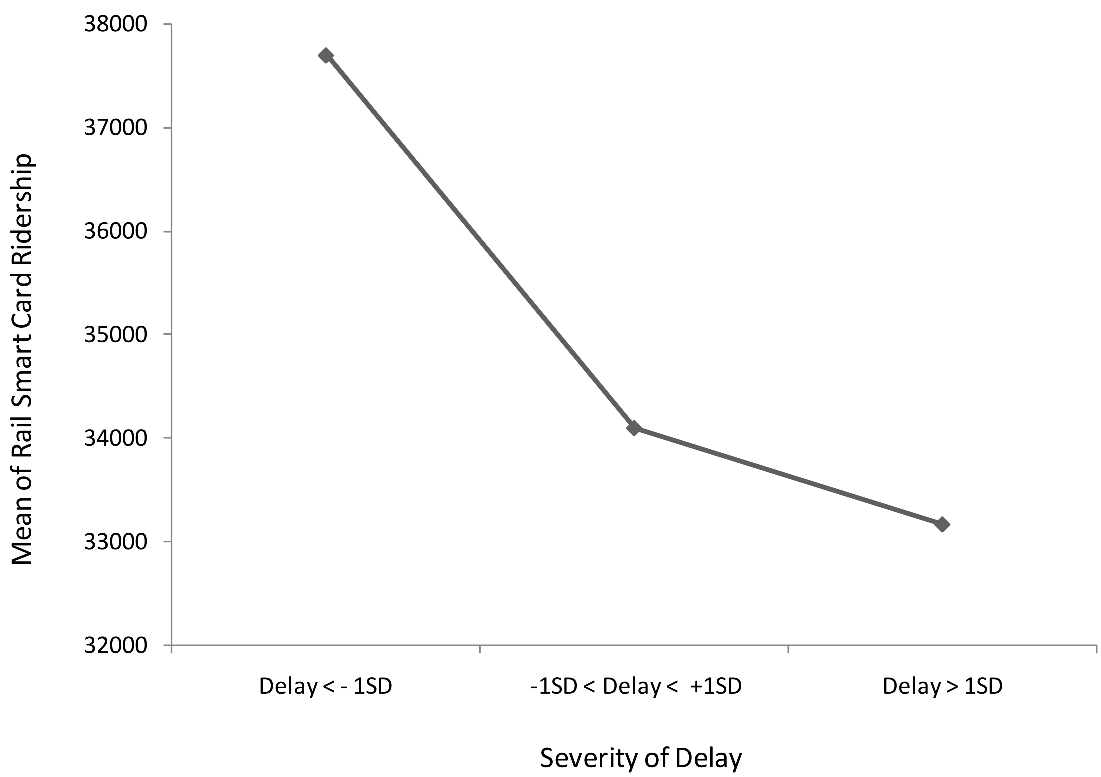
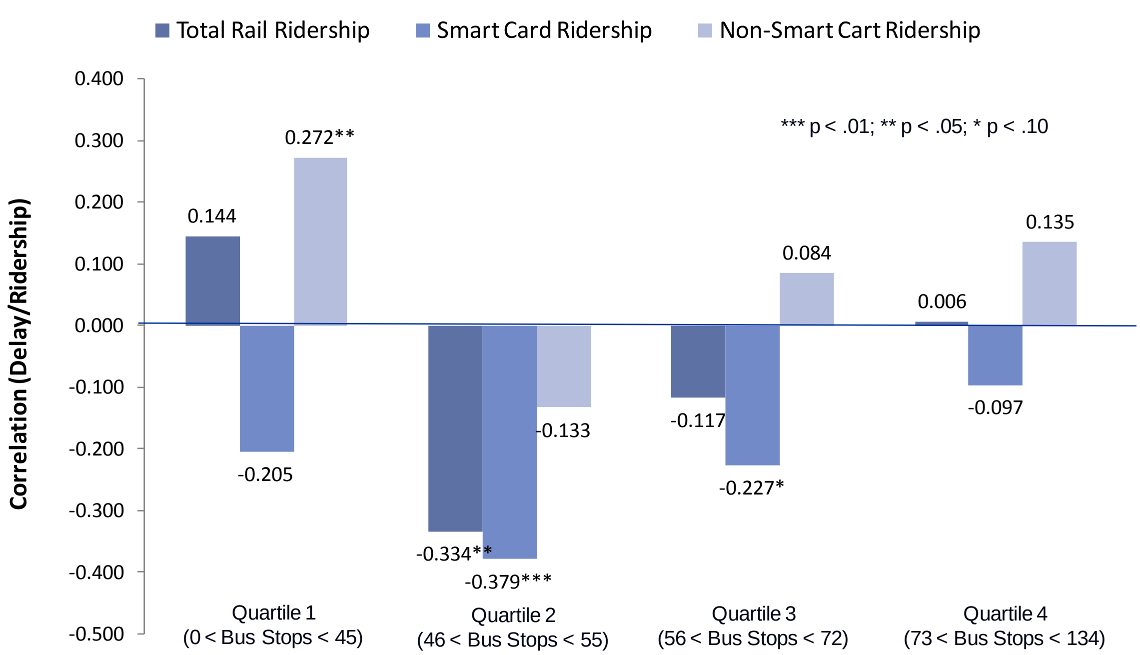


Figure 3 shows that the relationship between rail ridership and delays is not clearly affected by bus availability around train stations. The negative correlation between rail ridership and train delays is not necessarily stronger for stations with higher bus availability. Actually, the trend is towards a milder relationship but it is not linear. The results show that bus availability affects differently rail ridership depending on the type of fare. Rail ridership for Smart Cards users is significantly affected at station in quartile 2 and 3 but not in 1 and 4, meanwhile there seems to be no effect of delays on non-smart card ridership for most stations. Actually, only stations in quartile 1 show a significant relationship between delays and ridership, but even then, the relationship is positive and contra intuitive.

Figure 3. Bus Availability and Rail Ridership by Type of Fare



Discussion and Conclusions

This study suggests that there is a strong evidence to support most of the hypothesis. The lack of support for hypothesis 5 suggests that there are other factors that are more important in determining the sensitivity of ridership to delays than bus availability around train stations.

The pattern of behavior of rail ridership, depending on the train stations, may be better explained by the location of the stations than by the availability of buses. Because the availability of buses is related with the location of the station (the closer to O'Hare the station is, the lower amount of buses around the station are), the stations clustered in quartile 2 (Western, Belmont, Damen, and Chicago) tend to be located in the middle of the section between O'Hare and the Loop and they seem to be the most affected by train delays. This suggest that the ridership of the train stations closer to the Loop is less affected by delays not because there is more bus availability (stations in the Loop have the higher amount of bus availability) but because people use those train stations for different purposes (commuting, short trips within the city, etc.) while the other stations are used more to move in and out of the city.

Future research should aim at better understanding the relationship between train station location and its ridership sensitivity to delays in the system. In order to dig deeper in the study and have a more accurate understanding about how customers react to delays, more detailed data is needed about trains' departure and arrival times and actual train travel time.

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

1) Manage delays to reduce impact: Given that not all delays have the same effect in rail ridership, CTA should try to avoid having severe delays 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 allowed us to get an initial understanding at the effect of train delays on ridership but further research is need to better understand the effects of delays in customer's behavior to assist CTA in devising strategies to avoid potential losses of customers seeking other transportation alternatives. Future research aimed at understanding riders' behavior when exposed to critical incident would allow CTA to increase its knowledge about the negative effects of delays on ridership.

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Appendix A. Sample of a Rail Slow Zone Map