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The Effect of Information on Avoidance Behavior and Bicycle Transportation: a Study of "Spare the Air" and Bay Area BikeShare

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Cover Page Footnote

Acknowledgements to Nathan Chan for his assistance in organizing my data set and guiding me in the direction of how to use the data to assess my propositions.

1. INTRODUCTION:

Information alerts and awareness are becoming an increasingly important part of health regulation and environmental policy. Home Energy Reports are issued in areas to remind owners of their energy usage and efficiency [13]; the Environmental Health Agency requires companies to self-report their emissions in the Toxic Release Inventory, which is publicly released [10]; and metropolitan cities globally have warning systems for the public when air quality is below environmental standards [5]. The purpose of such systems is to create awareness as well as change human behavior as to better protect individuals and the environment.

Ozone is a highly observed pollutant for maintaining environmental and health standards. Ozone is formed through reactions between ozone precursors in the presence of sunlight and heat [9]. Thus, the prevalence of ozone formation will increase on warmer and sunnier days. According to W.B. Cutter and M. Neidell, this could partially explain the pervasive ozone levels seen in California.

The National Ambient Air Quality Standards (NAAQS) are in place to regulate ozone levels. Ozone violations are based on daily ozone concentrations and high ozone levels can be forecasted by emissions trends and weather [9]. Lowering ozone levels and attaining NAAQ levels is critical to avoiding regulation fees. Spare the Air (STA) alerts may be a more efficient method to achieve ozone levels. STA alerts are an effort that reduces emissions only during times when environmental conditions may be leading to higher ozone levels. From a policy perspective, STA's may allow for regulatory focus for only the days when it is important to avoid exceeding the NAAQ standards [3].

STA alerts, a smog alert, is a commonly known alert in the Bay Area of California. "Spare the Air" is a non mandatory day encouraging alternative forms of transportation. Thus, it allows the observation of individual's discretionary behavior on a non-mandatory approach. The purpose of STA's is to reduce ozone so levels may be maintained below NAAQ standards.

Human behavior in the presence of STA's is difficult to measure and unpredictable. STA's encourage the public to increase ride sharing and the use of public transportation yet, discourage exposure to high ozone levels outdoors. This creates counteracting incentives. Cutter and Neidell express three main counteracting incentives when people respond to STA's, which are detailed here:

1. Given people substitute higher ozone producing activities for lower ozone producing activities, traffic volumes will decrease and public transit use will increase.
2. Some individuals will reduce trips while others will respond by taking more trips due to decreased traffic and travel time; this will result in a free rider problem.
3. Individuals will see environmental health risks and respond by decreasing public transit and exposure to ozone.

The focus in this paper is concentrated on point three. This paper observes the Bay Area BikeShare as a form of public transportation that also exposes the user to environmental health risks on STA days.

BikeShare is a subscriber or customer bike sharing program where users may ride between stations for commuting or at leisure. This paper observes if STA days are an incentive for individuals using BikeShare; the objective is how users make transportation

decisions on STA days and assess the costs of high pollution exposure and the benefits and "warm glow" of decreasing ozone by using public transportation. Warm glow is a warm feeling or satisfaction felt when doing good for the environment [14]. As this paper focuses on biking rather than vehicular transportation, traffic patterns and travel time are not a measured factor in individual's decision making.

The San Francisco Bay Area is a particularly "green" area that has substantial focus on environmental policy and pollution reduction. Though there is public transportation in the form of ferries and buses through Golden Gate Transit and the Bay Area Rapid Transit System, efficient transportation is not as robust in other cities that have superior subway systems or rail systems. However, temperate weather, healthy lifestyle attitude, and a population that gravitates to the outdoors provide a suitable base for biking as a form of transportation. The Bay Area and its' active population provide an ideal location for observing biking frequency.

Biking frequency is observed through the choices of customers versus subscribers. Three hypothesis characterize this paper:

Hypothesis 1: Biking duration will decrease for customers on STA days.

Customers will consider the negative health effects of riding in increased ozone levels. The costs of health effects and monetary cost of using BikeShare for one day ($9) will outweigh the warm glow received from biking on an STA day [15]. Customers may substitute BikeShare for alternative forms of public transportation.

Hypothesis 2: Biking duration will decrease for subscribers on STA days.

Subscribers may experience two effects on STA days.

1. Subscribers may have a substitution effect. As subscribers already have a sunk cost of $88 to be a member of the BikeShare program, they do not incur an additional monetary cost of using BikeShare on an STA day [15]; their cost is exposure to increase ozone levels while biking. Subscribers will substitute BikeShare with an alternative form of public transportation so that they are still receiving the warm glow of reducing ozone levels that day by still ride-sharing.
2. Subscribers may also continue to ride on STA days but decrease their trip duration so as to expose themselves less to harmful air pollutants. This will be referred to as the health awareness effect.

Hypothesis 3: Longer trips (in excess of 30 minutes) will decrease for subscribers on STA days.

Similar to hypothesis 2, subscribes will experience either a substitution effect or a health awareness effect. Thus, as their biking duration decreases, they will be taking part in fewer longer biking trips.

The results suggest that regardless of if there is an alert, customers will ride farther than subscribers and subscribers are more likely to take shorter trips on STA days. The

results contradict the cost barriers to entry for customers and do not follow what would be expected as customers versus subscribers make behavioral decisions.

2. PAST RESEARCH ON THIS TOPIC:

Bike Share is becoming an increasingly researched topic. *BikeShare: A Review of Recent Literature* by E. Fishman (2015) observes the increasing availability of Bike Share programs globally and its effects. Bike Share began in the 1990's, and as of 2015, programs are available in 800 cities. Bike sharing is important financially as an efficient use of simple transportation and the major motivation for using bike share is convenience; it is easy to use and if you live close to a station, the probability of being involved in the program significantly increases. It was concluded that commuting is the primary purpose of bike sharing and males rather than females more often use the program. The importance of bike sharing as a form of public transportation is increasing rapidly but more research should be done on the impacts of bike share on health, the environment, and emissions.

There has been significant research on ozone advisory programs nationwide. In *Measuring the effectiveness of voluntary emission reduction programmes* by R.G. Cummings and M.B. Walker, the authors examined an equivalent STA program to that of the Bay Area in Atlanta, Georgia and its effects on daily transportation and travel activities. They found statistically insignificant effects on hourly traffic volumes with pollution alerts. In contrast, *The effects of ozone action day public advisories on train ridership in Chicago* by E. Welch, X. Gu, and L. Kramer had successful results when observing public transit traffic volumes during a comparable pollution advisory program in Chicago, Illinois. The authors found an increase in public transit volumes during peak commuting periods and a decrease during non-peak hours on ozone advisory days.

Past research on Spare the Air in the Bay Area is detailed in *Voluntary Information and Environmental Regulation: evidence from 'Spare the Air'* by Cutter and Matthew Neidell (2009). Cutter and Neidell observed the voluntary response to pollution alerts and its effect on public transportation through the Bay Area Transit System (BART). Their paper observed how pollution alerts reduce traffic volumes and slightly increase the use of public transit. What their paper failed to observe was alternative uses of transportation that are available to consumers on alert days including Golden Gate Transit buses and ferry system as well as Bay Area BikeShare. This paper adds value by observing an alternative form of transportation available to residents. In contrast to their paper, which also heavily focuses on traffic volumes as an effect to consumer choice, this paper excludes vehicular traffic, as it is not associated with the use of bicycle riding.

Additionally, there is a small study in the Bay Area examining individuals transportation decision choices in response to STA's. In *Quantification methods for identifying emission reductions resulting from seasonal and episodic public education programs* by E. Schreffler, a small telephone survey requested information on daily travel activities and concluded with statistical significance that there was a 4.8 percent reduction in trips on STA days.

Days of Haze: Environmental Information Disclosure and intertemporal avoidance behavior by Joshua Zibin and Matthew Neidell (2009) assess the effect of pollution alerts in Los Angeles on behavior of individuals at the Los Angeles Zoo and Observatory in Southern California. Their paper assesses variation in individual's response to initial alerts and cumulative alerts by observing Zoo and Observatory attendance for members and customers on non alert days, an alert day, and two consecutive alert days. Their results confirm that intertemporal substituting of activities during consecutive alerts is increasing over time with alerts. Similar to their paper, this paper considers the effect of alerts on consumer choices and if consumers or subscribers also consider intertemporal substitution with their transportation choices during alerts. A considerably important next step for this paper would be to observe the effect of consecutive STA alerts on bike ridership.

My paper seeks to continue to do research on the effects of bike sharing by considering behavior choices given current pollution environments. With substantial time and after further years of growth of bike sharing in the Bay Area, it will be important to assess the growth of Bike Share as a form of public transportation and its effects on reducing pollution and increasing environmental awareness in the area.

3. BACKGROUND:

BACKGROUND ON OZONE REGULATION:

Ozone is one of six common air pollutants that are heavily regulated by the Environmental Protection Agency (EPA). Ground level ozone is not emitted directly into the air but it is created by chemical interactions between nitrogen oxides (NOx) and volatile organic compounds (VOC) in the presence of heat and sunlight. Major sources of NOx and VOC include industrial and electric facilities, gasoline vapors, and especially vehicle exhaust [9]. 49% of Nox emissions in the San Francisco Bay Area, Sacramento Valley, and San Joaquin Valley are due to on road sources, with 55% percent from gasoline vehicles [3]. Ground level ozone can cause difficulties in breathing and have harmful effects on ecosystems.

As mentioned, ozone levels are exasperated with warmer temperatures and sunlight. California is particularly susceptible to increased ozone levels due to warmer temperatures, sunlight, and temperature inversion layers that lead to ozone formation as well as geography with mountains that "trap" pollutants in certain regions of the state [3]. While increased temperatures lead to ozone levels that peak at the warmest times of the year and day, the "trapping" effect can increase ozone levels as well.

There are no direct air quality standards for NOx and VOC, but National Ambient Air Quality Standards (NAAQS) are in place to regulate ozone levels. The Clean Air Act, amended in 1990, put into place regulatory levels for primary and secondary standards for different pollutants. Primary standards provide public health protection for sensitive populations such as children and asthmatics, while secondary standards provide public welfare protection for ecosystems and damage to public sources such as vegetation [12]. Ozone is regulated as both a primary and secondary pollutant.

NAAQS for ozone are based on daily measurements in parts per million (ppm). Ozone levels per day are based on peak observation rather than averages over time. Thus, to attain NAAQS for 8-hour ozone, "the 3-year average of the fourth highest daily maximum measured at each monitor within an area over each year must not exceed .08ppm" (40 CFR 50.9; see Federal Register of April 30, 2004 (69 FR 23996) [3]. Failure to meet the NAAQS's requirements results in costly repercussions and thus policy makers assess a variety of approaches to meet NAAQS and avoid fees [12].

One method for policy makers is to place the cost of avoiding NAAQS violations on firms by shifting the distribution of NOx and VOX levels. This requires extensive costs to firms to distribute and control pollution levels so that the maximum level of emissions will not result in an ozone violation [3]. The problem with this is that controlling NOx and VOX levels does not account for the variability in weather and human behavior – such as transportation – that can account for additional fluctuating levels of ozone.

The alternative approach, which Spare the Air works towards, is to avoid a violation by limiting pollution on days of projected high ozone levels. This method targets individuals. The objective is that individuals face lower costs to switch from normal automobile transportation to public transportation temporarily.

CALIFORNIA "SPARE THE AIR" POLICIES AND PROCEDURES:

"Spare the Air" is a California initiative that is part of the Bay Area Air Quality Management District (BAAQMD). The BAAQMD is focused on eliminating health problems caused by air pollution. They maintain and achieve air quality standards, have regulatory programs and reporting for air quality, and serve as an air authority for air quality development and establishing the Bay Area as a leader in emission reduction [17]. BAAQMD monitors air pollutant levels for 25 monitoring stations throughout the Bay Area for a variety of pollutants including ozone, carbon monoxide, nitrogen dioxide, sulfur dioxide, PM_{10}, and PM_{25}. Extensive air monitoring provides significant data for the BAAQMD to assess when to designate an STA day. BAAQMD has been issuing STA's since 1991 [3].

Spare the Air is itself is a program that encourages residents to be aware of their air pollution and improve air quality through alternative forms of transportation such as biking, walking, or public transportation. STA's encourage the public to increase ride sharing and the use of public transportation yet discourage exposure to high ozone levels outdoors. STA days in the summer season are when the forecasted ozone pollution, or smog is particularly high. In the winter, particulate matter, or soot, is a health concern, and STA days also include restriction to wood burning on that days. It is illegal to light a fire, barbecue, or any form of wood burning on a winter alert day [18]. As part of the STA program, the BAAQMD provides programs that help to subsidize costs for public transportation specifically on alert days.

An STA day is initiated for expected days of particular air pollution based on geographical observations of seven main districts: Alameda, Contra Costa, Marin, San Francisco, San Jose, Santa Clara, and Napa, and part of two districts: Solano and Sonoma. Alerts are issued when the ozone forecast is predicted to exceed 0.081 ppm as of 2003 and 2004 [12]. This trigger is linear and thus, health effects just above or just below this ozone level can be viewed as equivalent. If any one or more of these regions is forecasted to be

at or above this level, an alert will be posted for the following day for all geographic areas. STA alert are based off of forecasted and current pollution for each county using an Air Quality Index [1]. This is shown in Image 1. The AQI ratings are based on NAAQS for the pollutants listed above.

Image 1: Air Quality Index

Air Quality Index

The Air Quality Index, or AQI, much like an air quality "thermometer", translates daily air pollution concentrations into a number on a scale between 0 and 500. The numbers in this scale are divided into six color-coded ranges, with numbers 0-300 as seen below.

(0-50)	Good No health impacts are expected when air quality is in this range.
(51-100)	Moderate Unusually sensitive people should consider limiting prolonged outdoor exertion.
(101-150)	Unhealthy for Sensitive Groups Active children and adults, and people with respiratory disease, such as asthma, should limit outdoor exertion.
(151-200)	Unhealthy Active children and adults, and people with respiratory disease, such as asthma, should avoid prolonged outdoor exertion; everyone else, especially children, should limit prolonged outdoor exertion.
(201-300)	Very Unhealthy Active children and adults, and people with respiratory disease, such as asthma, should avoid all outdoor exertion; everyone else, especially children, should limit outdoor exertion.

STA's are posted for the following day through a variety of social media sources: subscribed email, on local morning and nightly news stations including ABC news, CBS news, in the local newspapers including the San Francisco Chronicle, Marin Independent Journal among others, broadcasted over local radio, the "Spare the Air" Facebook and Twitter page, on highways via electronic alert signs, and a notification can be received through text alerts and through the "Spare the Air" phone app [18]. If you live in the San Francisco Bay Area, a "Spare the Air" alert is rare to go unnoticed.

"Spare the Air" days are separated into the Winter Season, November 1^{st} till the last day of February, and the Summer Season, March 1^{st} to September 30^{th}. The 2014 Summer Season of my data set had 3 alert days, the 2014-2015 Winter Season had 23 Spare the Air Days, and the 2015 Summer Season had 4 alert days. The regression includes 30 Spare the Air days between September 1^{st}, 2014 and August 31^{st}, 2015 [17].

BAY AREA BIKESHARE

Bay Area BikeShare is a bike-sharing program that replicates the most commonly known bike share program, CitiBike, in New York City. BikeShare has access to 700 bikes at stations throughout the San Francisco Bay Area in San Francisco, Redwood City, Palo Alto, Mountain View, and San Jose. These are bike rack stations with locked blue bicycles. Image 2 shows the distribution of bicycle stations in the Bay Area.

BikeShare allows for individuals to use the bikes for transportation knowing that they will have a bike rack available at their destination and a bike available for their return. For example, in the San Francisco area there are 32 stations. It allows for subscribers who can use the bikes at any time and for customers who pay by credit card at the bike station for bike duration. The BikeShare program is incredibly affordable and also offered at the corporate level. Pricing is annual or based on biking duration [15]. Image 3 shows details of the program costs.

Image 2: BikeShare Station Distribution

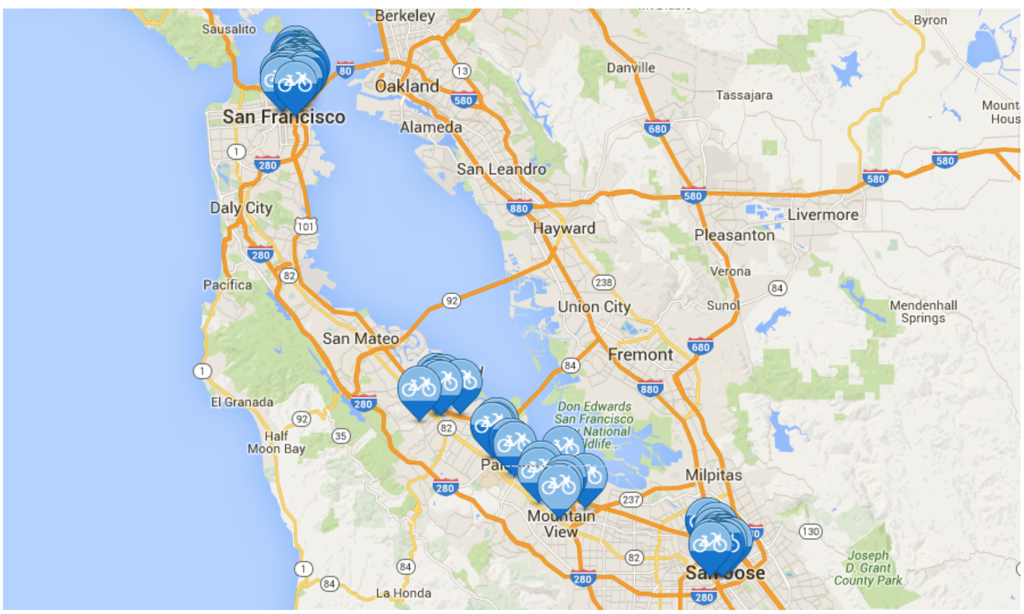
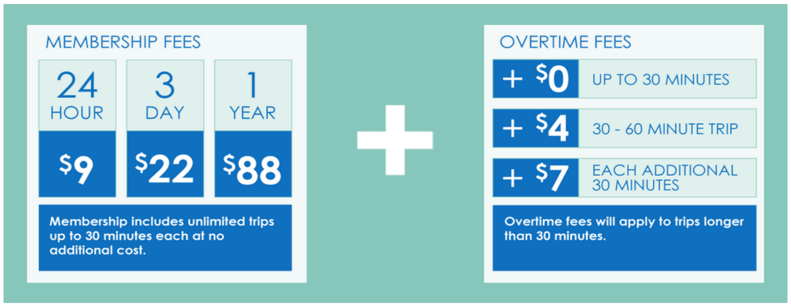


Image 3: BikeShare Membership Pricing



Considering the pricing, BikeShare is an affordable option for commuters and is also an option for customers, both local and tourists to the area, as a form of city transportation. Considering the proximity of the bike stations within the five Bay Area BikeShare districts, a ride over 30 minutes would be long for a commuter. Trips in the data set that are over this length are hypothesized to be tourists or individuals using the bike outside of a bike share station area where a bike would otherwise be checked in after 30 minutes. For STA days, trip durations exceeding 30 minutes are likely individuals willing to sacrifice the additional riding cost to achieve a "warm glow" of reducing ozone emissions.

4. DATA:

Bay Area BikeShare provides a robust data set. Though they have two years of data available on their website this regression uses the 2014-2015 trip and weather data that begins on September 1st, 2014 and ends on August 31st, 2015 [5]. This yearly data set is over 350,000 entries where each entry represents any time that a bike was used in this program for any of the days of the 2014-2015 year. It includes a trip data set that includes the identification code of the bike checked out, the station street name that it was checked out from and checked into, the bike station code, the time of check in and check out, the duration of the ride in seconds, the user, and if that user is a customer or a subscriber to the BikeShare program. The data is incredibly accurate as the duration of biking and bike location is computer monitored ensuring that the ride time and number of rides are all accounted for

The included weather data set provided maximums, minimums, and averages for the weather for the 365 days of the year including temperature, precipitation, dew point, humidity, wind speed, gust speed, event type (rain, lighting, thunder, combination etc.). For the purpose of this regression, the weather data was aggregated using only certain average parameters: temperature, precipitation, and wind speed. It was hypothesized that these weather effects would be most influential on the daily use of BikeShare as a mode of transportation. Table 1 provides details of the BikeShare Data Set.

Table 1: BikeShare Data Set Summary for Spare the Air Days

		Spare the Air Day				
Variable:		Observation	Mean	Std. Dev	Min	Max
Duration		354,011	902.102	2870.891	60	86,381
Start Date					9/1/14	
End Date						8/31/15
Mean Avg Temp	(degrees F)	354,011	62.488	6.368	41.8	80.4
Mean Avg Wind	(mph)	354,011	6.148	2.486	1.2	18
Mean Avg Precip	(inches)	354,011	0.013	0.076	0	1.67
Mean Degree Day 70	(degrees F)	354,011	8.161	5.608	0	28.2

When aggregating the data, it was necessary to manipulate the set for the zip code of the bike user to correlate the correct dates with the weather. The weather data set has 1825 entries – 5 entries per day, one for each of the 5 zip codes that compose the Bay Area Bike Share Program: San Francisco, Redwood City, Palo Alto, Mountain View, and San Jose. As these areas are within a 50-75 mile radius of one another and experience different weather patterns due to their coastal or inland location, it was important to aggregate the zip code weather and take an average for each day. The effects of such aggregation will be explained further in the "Results" section.

It was not possible with my resources to match each specific zip code to each trip for multiple reasons. Firstly, the zip code of the user is not necessarily the zip code of the weather location; Secondly, hundreds of users, both subscribers and customers, opted out of registering their zip code and thus it would be difficult to match the weather to their bike trip. For any unreported zip code, it was reported as 0 in the data set. Lastly, the bike check-in and check out stations are by street corner. Considering in one zip code there may be over 30 different BikeShare stations, it would be very difficult to place the specific weather zip code to that BikeShare location. Though this is possible with ample time, it would result in a substantial part of the data set with unreported zip codes to be removed. In an ideal data set, it would be possible to attribute each subscriber or customer zip code to each specific bike trip.

Though BAAQMD, Spare the Air, and California Pollution websites provided ample pollution information, it did not include the dates of individual Spare the Air days. These Days were obtained through the Spare the Air Facebook page. Any day that there is an alert it is publicized on their Facebook timeline the day before. By navigating through Facebook history, it was possible to obtain the 30 Spare the Air days that occurred during the yearlong data set. Details on these days over the Winter and Summer Season are shown in Table 2.

Table 2: Spare the Air Days September 1st, 2014 to August 31st, 2015

Summer 2014 Beginning September 1st, 2014		Winter 2015: October 1st -February 28th, 2015			Summer 2015 March 1st-August 31st, 2015	
Dates	Total	Dates		Total	Dates	Total
9/11/14	3	11/9/14	1/8/15	23	7/28/15	4
9/12/14		11/25/14	1/9/15		7/1/15	
10/3/14		11/26/14	1/10/15		8/6/15	
		11/27/14	1/11/15		8/16/15	
		12/28/14	1/12/15			
		12/29/14	1/15/15			
		1/2/15	1/16/15			
		1/3/15	1/17/15			
		1/4/15	1/24/15			
		1/5/15	1/25/14			
		1/6/15	2/3/15			
		1/7/15				

In the data set, there were sufficient outliers. The greatest outlier was for 17 days of biking duration. For the regression, the data was only for bike durations between 60 seconds and 24 hours (86,400 seconds). This removed 141 observations leaving 354,011 observations for regressions.

Spare the Air and no alert days are separated into a Spare the Air, *STA,* dummy variable that is detailed in "Empirical Strategies and Methods". The dummy variables in Table 3 are before removal of outliers. The former has 25,644 observations and the latter has 328,508 observations.

Though the validity of outlier removal can be disputed, it was justified in this data set considering the ridership that BikeShare promotes. Durations exceeding 24 hours were assumed to be bicycles that had been under repair, misused, or missing. Though in the costs detailed in "Background" it is possible to purchase a 1 day or 3 day membership, each trip that exceeds 30 minutes induces an addition $4-7 USD cost. Thus, even such a membership, bikes should be returned in 30 minute intervals; ideally, this would maximize the data set at 30 minutes if everyone did not incur additional travel costs.

5. EMPIRICAL STRATEGIES AND METHODS:

To answer the two propositions, two main models were creating observing the effects of alert days, subscriber type, and trip length on initial variables that effect duration.

The initial model of duration is:

$$\text{Duration}_t = \beta_1 \text{degreeday70}_t + \beta_2 \text{meanavgwind}_t + \beta_3 \text{meanavgprecip}_t + c \qquad (1)$$

Where $duration_t$ is the duration of a bike ride on date t as a factor of the average temperature, wind speed, and precipitation on date t in the Bay Area. The variable, *degreeday70*, is not a binary variable. It is hypothesize that the ideal temperature for biking is 70 degrees Fahrenheit; thus, a "cooling day" is days where the temperature is above 70 degrees whereas a "warming day" is a day that is below 70 degrees. This variable shows

how much mean average temperatures across the five cities are deviating from the ideal 70 degree temperature.

It is hypothesized that an increase in wind speed and precipitation will decrease biking duration. Since temperature is a degree day, duration will also decrease as temperature deviates from the ideal. Temperature is an important variable as an increase in ozone is correlated with an increase in temperature during the summer months.

For this regression, I had two dummy variables: *STA* is equal to 1 on any Spare the Air day, 0 on a non alert day; *group*, which represents the type of BikeShare user, which it is equal to 1 (*group2)* if the user is a BikeShare subscriber, and equal to 0 (*group1)* if the user is a customer. The frequency of the dummy variables is shown in Table 3.

Table 3: Dummy Variables – Spare the Air and Subscriber Type

Spare the Air	Frequency	Percent	Cumulative
0	328,508	92.76	92.76
1	25,644	7.24	100
Total	354,152	100,000	

Subscriber Type	Frequency	Percent	Cumulative
Customer	43,955	12.41	12.41
Subscriber	310,217	87.59	100
Total	354,152	100,000	

The frequency of Spare the Air days represents the number of bike rides that occurred over the 30 spare the air days in the 2014-2015 year. The frequency of subscribers represents the number of subscriber ride over this year; subscribers represent a significant 87% of the data set.

To observe the effects of the different interactions between the dummy variables, four interaction variables were created: *C-NoAlert*, *S-NoAlert*, *C-STADay*, and *S-STADay* where *C* represents *group2* (customers), *S* represents *group1* (subscribers), *NoAlert* is when *STA* = 0 and *STADay* is when *STA* = 1. So for the interaction variable, *C-NoAlert*, this is the interaction of customer duration on a non alert day.

To estimate the impact of a Spare the Air day the model is the following:

$$\log(\text{duration})_t = \beta_1\text{degreeday}_t + \beta_2\text{meanavgwind}_t + \beta_3\text{meanavgprecip}_t + \beta_4\text{C-NoAlert} + \beta_5\text{C-STADay} + \beta_6\text{S-STADay} + c \quad (2)$$

This model observes the logarithm of duration relative to being a subscriber on a non alert day, *S-NoAlert*. The variable *C-NoAlert* is the change in duration of a customer on a non alert day relative to *S-NoAlert*. Variable *C-STADay* is the change in duration of a BikeShare customer on a Spare the Air day relative to *S-NoAlert*. Variable *S-STADay* is

the change in duration of a BikeShare subscriber on a Spare the Air day relative to *S-NoAlert.* Duration is logged to achieve stronger correlation in the model.

The duration of the rides is also considered with prices. In the Image 3 above, rides over 30 minutes regardless of being a customer or subscriber required an additional cost. To analyze my second hypothesis, it was necessary to observe the frequency of longer trips taken. The variable, *longtrip*, is for durations that exceed 30 minutes.

The frequency of long trips are estimated using the following probit model:

$$\text{Longtrip} = \beta_1 \text{degreeday}_t + \beta_2 \text{meanavgwind}_t + \beta_3 \text{meanavgprecip}_t + \beta_4 \text{C-NoAlert} + \beta_5 \text{C-STADay} + \beta_6 \text{S-STADay} + c \tag{3}$$

This model observes the long trip likelihood relative to being a subscriber on a non alert day, *S-NoAlert*. The variable *C-NoAlert* is the likelihood of long trips given someone is a customer on a non alert day relative to *S-NoAlert*. The variable *C-STADay* is the likelihood of long trips given someone is a customer on a Spare the Air Day relative to *S-NoAlert*. The variable *S-STADay* is the likelihood of long trips given someone is a subscriber on a Spare the Air Day relative to *S-NoAlert.*

6. RESULTS:

Spare the Air is a somewhat contradictory alert as it encourages the use of alternative and public transportation on alert days while encouraging the prevention of adverse health effects on a heavy pollution day by minimizing outdoor exposure. BikeShare is a public form of transportation that additionally causes riders to be susceptible to environmental pollution. This poses interesting results.

Considering customer and subscriber costs and benefits with BikeShare is critical to understanding users behavioral decisions. Table 4 details the cost breakdowns for both types of users on STA or non alert days. Pricing for Table 4 is also detailed in the Introduction. Table 4 additionally considers the warm glow received from reducing emissions and biking on an STA day as well as the negative health effects of biking during higher ozone levels.

Table 4: Cost Benefit Breakdown

	Customer		**Subscriber**	
	No Alert	STA Day	No Alert	STA Day
Membership Fee: yearly $88; daily $9	$9	$9	$88 sunk cost	$88 sunk cost
30-60 minute Trip	$4	$4	$4	$4
Additional 30 min	$7	$7		
Environmental Effects		"warm glow"		"warm glow"
Health Effects		negative health effects		negative health effects

What is important to consider when interpreting the results is that customers and subscribers can both switch away from BikeShare at no additional cost. Customers, however, need to pay to use the bike for the first 30 minutes, which should result in a larger cost barrier to entry for customers than subscribers. That costumers have greater costs should support Hypothesis 1.

Equation (2) Results:

The first set of results in Table 5 show the duration for the three interaction variables relative to the fourth interaction variable: being a subscriber on a non alert day.

Table 5: Equation (2)

Logarithm duration relative to being a subscriber on a non alert day, *S-NoAlert*.

Variable	Subscriber/No Alert	
Customer/No Alert	1.1096	
C-NoAlert	[0.0035]	***
Customer/ "Spare the Air" Day	1.1287	
C-STAday	[0.0112]	***
Subscriber/ "Spare the Air" Day	0.0061	
S-STAday	[0.0048]	
Degree Day 70	-0.0018	
	[0.0002]	***
Mean Avg Wind	0.0007	
	[0.0005]	
Mean Avg Precip	0.0084	
	[0.01498]	

** significant at 10%*
*** significant at 5%*
**** significant at 1%. Standard errors clustered on duration in brackets.*

This regression shows that duration as a customer is greater regardless of it is a Spare the Air day or a non alert day at the 1% level of significance. Customer duration on non alert days increase by 111% relative to subscribers on non alert days and customer duration on STA days increase by 114% relative to subscribers on non alert days. This suggests that customers also want to help the environment and use alternative transportation on STA days. This negates Hypothesis 1.

Interestingly, the duration for subscribers on STA days does not significantly increase or have any statistical significance. This contradicts Hypothesis 2 that duration would decrease for subscribers on STA days. That duration for subscribers on STA days only increases by 0.6% suggests that subscriber's behavior on these days is unchanged or that there are subscribers that ride further while others do not ride at all.

These results contradict the cost barrier for customers in Table 4. It would be expected that customers would deter from being exposed to negative health effects on STA days more so than subscribers because of the daily and additional riding costs to use BikeShare as a customer.

As temperature fluctuated away from the idyllic average of 70 degrees, duration decreased at the 1% level of significance; this decrease in duration is expected for this degree day variable. Precipitation and wind both unexpectedly increased duration but by an almost imperceptible percentage. These variables were also not significant.

Equation (3) Results:

The second set of results in Table 4 show the long trip likelihood for the three interaction variables relative to the fourth interaction variable: being a subscriber on a non alert day. A long trip is a trip that is in excess of 30 minutes. It was expected that subscriber's long trip likelihood will decrease on STA days as subscribers will be able to substitute using BikeShare for an alternative transportation with no additional cost to their membership; this will reduce their personal exposure to increased pollution on STA days.

Observing the long trip likelihood assesses BikeShare users preferences that may change with alert information. On an STA day, using BikeShare as an alternative form of transportation and gaining the "warm glow" of helping the environment may outweigh the potential health consequences of breathing heavier pollution for a rider. In contrast, opting to not use BikeShare on an STA day shows that the health awareness effect outweighs the warm glow effect.

Table 6: Equation (3)

Probit Regression – Frequency of Long Trips relative to being a subscriber on a non alert day, *S-NoAlert*

Variable	Probit Regression (1)	
Customer/No Alert	1.9787	
	[0.0105]	***
Customer/ "Spare the Air" Day	1.9508	
	[0.0247]	***
Subscriber/ "Spare the Air" Day	-0.0649	
	[0.3264]	**
Degree Day 70	0.0027	
	[0.0009]	***
Mean Avg Wind	-0.0023	
	[0.0023]	
Mean Avg Precip	0.3736	***
	[0.0660]	

** significant at 10%*
*** significant at 5%*
**** significant at 1%. Standard errors clustered on duration in brackets.*

This probit regression shows that customers regardless of if it is an STA day likely to take longer trips rather than shorter trips relative to a subscriber on a non alert day. A customer on a non alert day will more likely take a greater amount of longer trips than on an STA day. Subscribers on STA days are likely to take *fewer* longer trips relative to a subscriber on a non alert day; since subscribers on STA days have a negative coefficient, they are more likely to take shorter trips. This is true to Hypothesis 3. It shows that the health awareness effect is greater than the "warm glow" of using alternative transportation for subscribers. All the results of the probit regression are statistically significant except for the effect of wind on the likelihood of long trips.

Like in Table 5, Table 6's results contradict the cost barrier for customers in Figure 4. It would be expected that customers would deter from being exposed to negative health effects on STA days more so than subscribers because of the daily and additional riding costs to use BikeShare as a customer. That customers opt to take more longer trips than shorter trips is also opposite of what is expected; customers would be paying an addition \$4 and possibly an addition \$7 depending on the length of their long rides. Cost barriers do not deter customers' behavior on STA days.

In contrast to the first regression, variance from the degree day results in a positive likelihood of longer trips at the 1% significance level. Additionally, precipitation results in a positive likelihood of longer trips. This seems unintuitive but is rational given the breakdown on precipitation in the data set.

As mentioned, the weather data is aggregated across the five Bay Area city zip codes; on a given day, it is possible that there is heavy precipitation south in San Jose, but minimal if zero precipitation in San Francisco given the geography of the region. Thus, while precipitation my hinder the use of BikeShare in one zip code, duration may have no change or a significant change in another zip code experiencing no precipitation. The overall effect is that rain makes biking more desirable elsewhere.

FURTHER THOUGHTS ON RESULTS:

That customers ride farther regardless of the day highlights the discrepancies between types of BikeShare users. What is most perturbing with customers is that they are likely to have longer durations or longer rides any time and particularly on STA days. Customers will thus, more often, face the additional riding cost of at least \$4 in addition to a \$9 daily cost. In contrast, subscribers do not face an additional cost as they already have a sunk cost of \$88 for the year long membership.

Considering costs, it would be expected that subscribers would be more likely to ride on STA days as it is of no additional cost to them given their ride is shorter than 30 minutes. Alternatively, customers face a cost of \$13 *and* expose themselves to pollutants when they ride on an STA day; yet, customers still ride more often and for longer on STA days than subscribers. The motivation for customers to neglect the cost to ride is unclear.

That the duration decreases for subscribers during a Spare the Air day raises questions about the effect of the Spare the Air alerts. If duration decreases as a result of the health awareness effect, what is the effectiveness of individuals using alternative forms of transportation or public transportation on alert days? Is individual's behavior towards using BikeShare affecting the anticipated decreases in ozone levels on forecasted high ozone

days? The results raise the question of what can be done to make STA's more effective or BikeShare more desirable. A few policy ideas came to mind:

> Additional costs for longer rides can be eliminated for BikeShare on STA days. This may encourage subscribers that may have ride durations that exceed 30 minutes to use BikeShare on STA days without a time cost. Since the results have shown that costs do not hinder customers, it may not change a customer's likelihood of riding. The issue posed by free ridership is a limited number and available bicycles.
>
> Transportation fees can be put in place to discourage individual transportation. Such a fee could be increased bridge toll on STA days for the following Bay Area bridges: the Dumbarton Bridge, Golden Gate Bridge, Richmond-San Rafael Bridge, San Francisco-Oakland Bay Bridge, and San Mateo-Hayward Bridge.

CONCLUSIONS:

Assessing the effectiveness of information is an important part of environmental policy. As mentioned in Cutter and Neidell, "given that numerous areas throughout the country offer similar programs such as Sacramento, CA, Atlanta, GA, Charlotte, NC, Houston, TX, and Pittsburg, PA, to name a few, evaluating their impact is necessary to determine how these programs can be best incorporated into state and local efforts to meet air quality standards".

The results showed that duration as a response to STA's for subscribers is unchanged or decreases whereas customers will continue to ride more and are more likely to ride farther whether it is an STA day or not. This contradicts cost barriers to entry for customers and poses questions as to why customers' decisions are opposite to what is expected; it verifies the ambiguity in understanding individual's behavior. Part of what the model of BikeShare and STA days cannot capture is seasonality or altruistic decision making.

An additional step in considering alerts is the effectiveness on ozone and pollutants over time. Bay Area BikeShare is a two-year old program that is exponentially growing. Over time, will it increase in popularity for consumers and subscribers? Thus, the effect that the BikeShare program will have on pollution over time is unclear. What will be important in assessing the effect of BikeShare as a whole is really understanding consumer choice with alerts; is an individual's use of BikeShare on alert days a necessity or a voluntary choice for the rider.

Considering the results, it would be important to consider alternative forms of transportation that *also* reduce air pollutant exposure such as the Golden Gate Ferry transit, Golden Gate Bus transit, and Muni, the San Francisco bus system. These may all be appealing forms of transportation on days that do have these STA days. This paper also observed the effect of STA's on ridership over the entire day. A further step would be to observe the STA effect of each hour during the day. Commuter trips are concentrated in rush hours periods; this could allow for observation of discretionary versus commuter trips. Similarily to *Daze of Haze* by Zivin and Neidell, it could be interesting to observe the effect of consecutive alerts and intertemporal behavior.

Overall, the results have posed interesting questions on further research on information alerts. Unexpectedly, the results have exposed the unpredictability in behavior given costs and barriers to entry. Costs provide another level by which the effectiveness of information alerts can be observed.

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