Measuring Traffic Reduction from Bicycle Commuting

Submission Date: November 15, 2013

Number of Words: 5,182
Number of Figures and Tables: 7+1=8

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ABSTRACT

Many claim that increasing bicycle commuting can reduce motor vehicle traffic, but can this reduction be measured? To address one aspect of this question, this study uses bicycle to work day events as an experiment to explore what happens to motor vehicle volumes when bicycle traffic volumes double. Bike to Work Day is a regular event in many communities which encourages commuting by bicycle on one day each year. Boulder, Colorado, is a community with relatively high participation in the event and was therefore chosen as an example city to investigate this question. Bicycle and motor vehicle traffic counts from continuous counters on Bike to Work Day were compared to comparable workdays. Bicycle counts roughly doubled on Bike to Work Day compared to comparable workdays. Motor vehicle counts on Bike to Work Day were lower than comparable Wednesdays in 88% of the 16 cases studied and significantly lower at the 80% confidence level in 31% of the cases. The drop in motor vehicle counts observed is of the order of magnitude expected based on the increase in cycling observed. A one-tailed, paired t-test provides evidence that the drop in traffic counts on Bike to Work Day is significant at the 95% confidence level compared to other summer Wednesdays. These results suggest that, for some, bicycling can be a practical alternative to commuting by motor vehicle and demonstrate that corresponding decreases in motor vehicle traffic can be measured.

INTRODUCTION

Replacing motorized trips with bicycle trips may lead to reductions in congestion, noise, and pollution as well as the potential for human health improvements through physical activity (*1*). This research investigates how traffic volumes in one city, Boulder, Colorado, have been impacted by bicycle to work events in order to examine one aspect of the viability of bicycle use to replace motor vehicle use.

Bike to work day events are held in cities around the world to encourage workers to bike commute on a particular day each year. These events often feature free food, prizes, and team competition. While events abound, little research has been done to measure the impact of these events on motor vehicle traffic volumes in cities.

This paper uses bicycle to work events with high participation as an experiment in which measurably increased cycling provides the conditions to answer the question: can a corresponding reduction in motor vehicle traffic be measured? Daily counts of cyclists and motorists on area paths and roadways on Bike to Work Day are compared to average summer workdays. While this method cannot reveal the total car trips reduced, it provides one measure of whether motor vehicle use may have been reduced by bicycle travel. If this phenomenon can be observed on one day, it supports the conclusion that bicycle use not only can hypothetically reduce motor vehicle use, but has done so.

LITERATURE REVIEW

The question of whether bicycle trips substitute for trips taken by motor vehicle has been tackled by many researchers, but the specific approach of investigating traffic changes related to a specific event, like Bike to Work Day, is uncommon in the literature. This literature review will begin with a general discussion of the research on substituting bicycle trips for motorized vehicle trips and end with a detailed discussion of research surrounding Bike to Work Day and similar events.

The Search for Evidence that Increased Bicycling Reduces Motor Vehicle Trips

The rational for funding for bicycle infrastructure and encouragement, including Bike to Work Day events, is sometimes linked to efforts to reduce congestion and improve air quality (*2*). The assumption is that if more people cycle to work, fewer will drive, and there will be less traffic congesting roadways and fewer pollutants from tail pipes. While there is a basic logic to this argument, the concept of induced demand, or the "triple convergence principle" as Anthony Downs calls it, plays a role (*3, 4*). For example, space on the roadway vacated by drivers switching to cycling may be quickly taken up by other drivers and result in no change in congestion. However, in the short term, such as a one-day event, induced demand might not have time to take effect.

Research on quantifying short or long term substitution of bicycling for driving is sparse to non-existent, though efforts to estimate potential benefits from such substitutions are frequent. For example, the Rails-to-Trails Conservancy published an estimate of potential benefits of drivers switching to walking and bicycling for short trips in terms of fuel savings and emission reductions (*5*). Other such estimation efforts have been conducted in for the San Francisco Bay Area and Midwestern U.S. cities (*6, 7*).

Knowing whether a given bicycle trip is substituting for a trip that would have been made by motor vehicle is difficult to pin down, as one can never truly know what would have happened. Despite this, researchers have used surveys to ask cyclists what

they would have done and found varying rates of substitution. For example, a study in five cities found that between 25% and 86% of cyclists intercepted on paths say that they would have otherwise driven (*8, 9*). While this line of research helps understand if cyclists would have driven, it still cannot prove a reduction in motor vehicle trips. Down's triple convergence principle may come into play such that the space vacated by the driver who has recently chosen to bicycle maybe filled by others who see unused capacity on the roadway. Fortunately, a one-day event may avoid some of this because other drivers would likely not have time in a single day to adjust to additional capacity on the roadway by choosing a different route or time of day to travel.

Bike to Work Day Background

According to the Alliance for Biking and Walking, the first Bike to Work Day event was organized by the League of American Wheelmen, now the League of American Bicyclists, in 1956. The Alliance reports that at least 43 cities around the country participated in the event in 2010 with participation varying from 75 to 17,093 adult riders per community with the highest participation recorded in the Denver metro area (*10*). Currently in the U.S., Bike to Work Day events are usually held on the third Friday of May, but this varies by location and climate. For example, Colorado cities hold bicycle to work events on the fourth Wednesday of June to avoid inclement weather.

Some work has been done to document cyclist behavior on and as a result of Bike to Work Day events. A study from Victoria, Australia, documented the success of Bike to Work Day events in their ability to encourage first time riders to continue to ride to work (*11*). A study of Bike to Work Day participants in Denver showed that the event was successful in encouraging existing bike commuters to bike commute more often, and frequent and occasional bike commuters to ride more for utilitarian purposes (*12*). According to a survey of Bike to Work Day participants conducted by the Denver Regional Council of Governments, roughly 70% of participants drive alone when not commuting by bicycle (*13*).

Few reports even mention the impact of bike to work events on motor vehicle traffic. The San Francisco Bicycle Coalition, reported bicycle volumes exceeding motor vehicle volumes on a main road in downtown San Francisco on Bike to Work Day 2007 (*14*). In the Denver area specifically, a preliminary investigation of pedestrian, bicycle, and motor vehicle counts in the Denver metropolitan area, by Colorado Department of Transportation (CDOT) staff, found an average increase in bicycle and pedestrian counts of 42% over six sites and decreases in motor vehicle traffic of 0.35% to 2.93% across the metropolitan area on Bike to Work Day in 2010 (*15*). However, no studies have documented a statistically significant drop in motorized traffic counts on a Bike to Work Day.

DATA

In order to investigate whether trips by bicycle are replacing trips by car on Bike to Work Days, a community which has both successful Bike to Work Day events and data to support that claim should be studied. Boulder, Colorado, has been holding Bike to Work Day events since 1977. From 2005 to 2010 participation varied from an estimated 5,000 to 8,000 in a city of roughly 100,000 residents (*16-18*). This rate compares favorably to other such rates reported by the Alliance for Bicycling and Walking (*10*). The Alliance

also reports Denver metro area participation, which includes Boulder, varied from 17,000 to 35,000 from 2007 to 2010 and was the highest of the 27 U.S. cities studied in 2009 and 2010 (*10*). This high participation should make a change in vehicle volumes easier to detect.

Bicycle and motor vehicle traffic counts from continuous counters in the Boulder area were examined. The city currently has inductive loop bicycle counters at 25 stations on paths, on-street bike lanes, and road shoulders around the city as shown in Figure 1 (*19, 20*). Some of these locations offer counts on multiple paths and most separate bicycle counts by direction. Data from the path stations are available from 1999 to present. Data from the on-street stations are available from 2010 to present.

While no permanent automatic traffic recorders (ATRs) exist within the city limits, automated photo red-light enforcement cameras at three stations at two locations (north and southbound 28th St. at Canyon Blvd. and southbound 28th St. at Arapahoe Ave.) in the city are capable of also counting traffic. Counts from these devices were provided by the city of Boulder for 2008 to 2010. The accuracy of this count method is not known, but since it is the change in counts that is of interest in this study, adjustment for accuracy is not necessary, so long as errors are consistent over time. Data from these three photo red-light stations were used as well as counts from a two-directional CDOT ATR on a major highway (US36) approximately five miles southeast of the city limit near McCaslin Boulevard in Superior, Colorado (*21*). Data from this site were analyzed in both directions for 2005 through 2010.

For the purposes of this study only five years of the available data were considered: 2005 and 2007 to 2010. The study was limited to those years when both bicycle and motor vehicle counts were available. The daily high temperature on Bike to Work Day was 80 degrees Fahrenheit or above for all five study years, indicating that low counts due to cool temperatures should not be expected at these events, though brief rain and thunderstorms were noted for 2005, 2008, and 2009 events(*22*).

METHODS

Examination of the bicycle count data shows that greatly increased bicycle counts can be observed on Bike to Work Day itself, but not usually on prior or subsequent days (Figure 2). This indicates that the impact of Bike to Work Day is isolated primarily to the day itself. Figure 3 shows that bicycle use in general is highest on Tuesdays and Wednesdays with the lowest counts during the weekend, indicating a commuter pattern.

Since the impact of Bike to Work Day on counts is concentrated to the day itself, it was reasonable to compare, for each year, Bike to Work Day bicycle and motor vehicle counts to the average counts for Wednesdays in June and July, excluding Bike to Work Day, and to the average Tuesday, Wednesday and Thursday, excluding Bike to Work Day. Stations with fewer than six days of such counts in a given year were excluded.

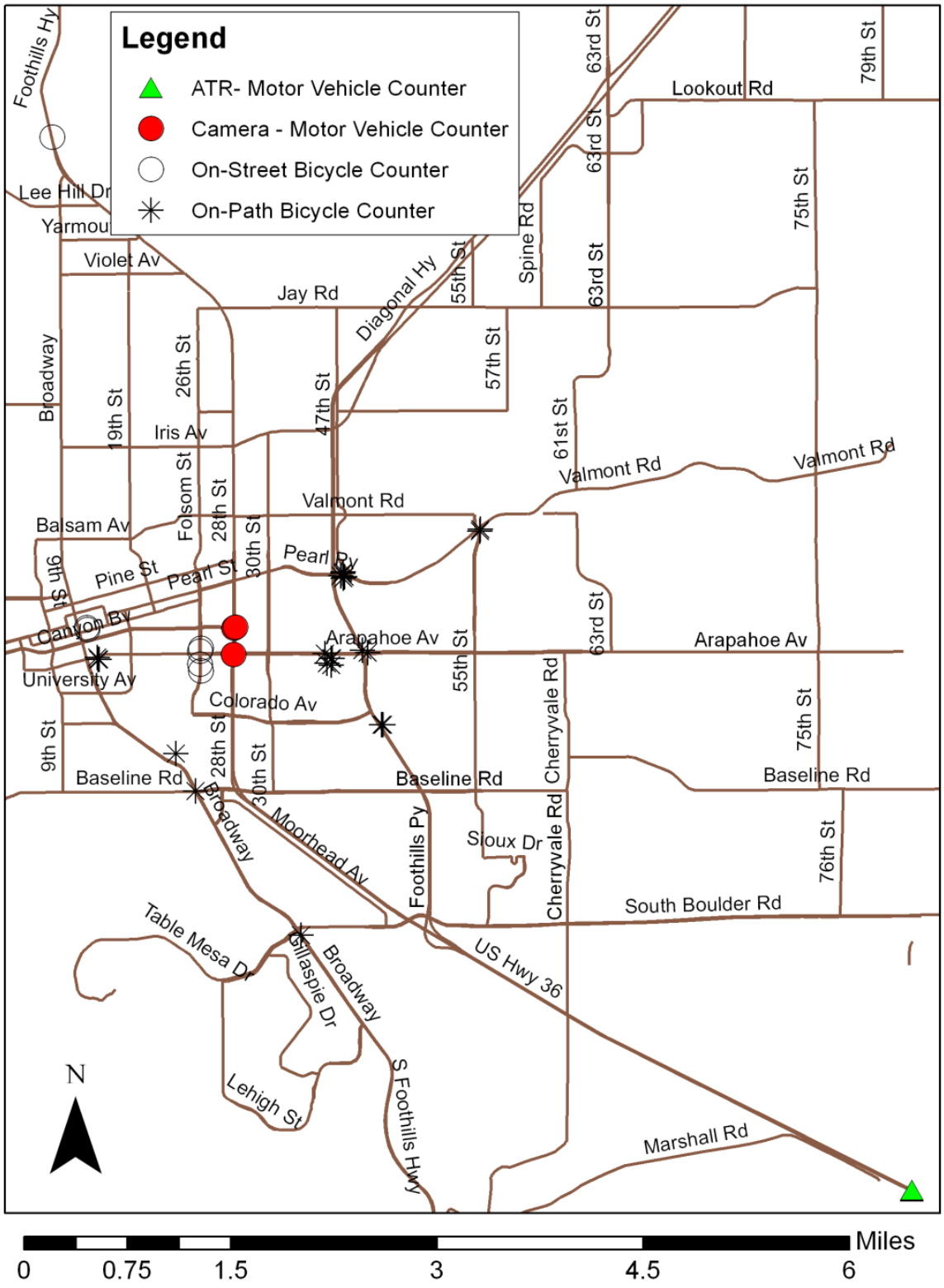

FIGURE 1 Automated Traffic Count Locations in Boulder.

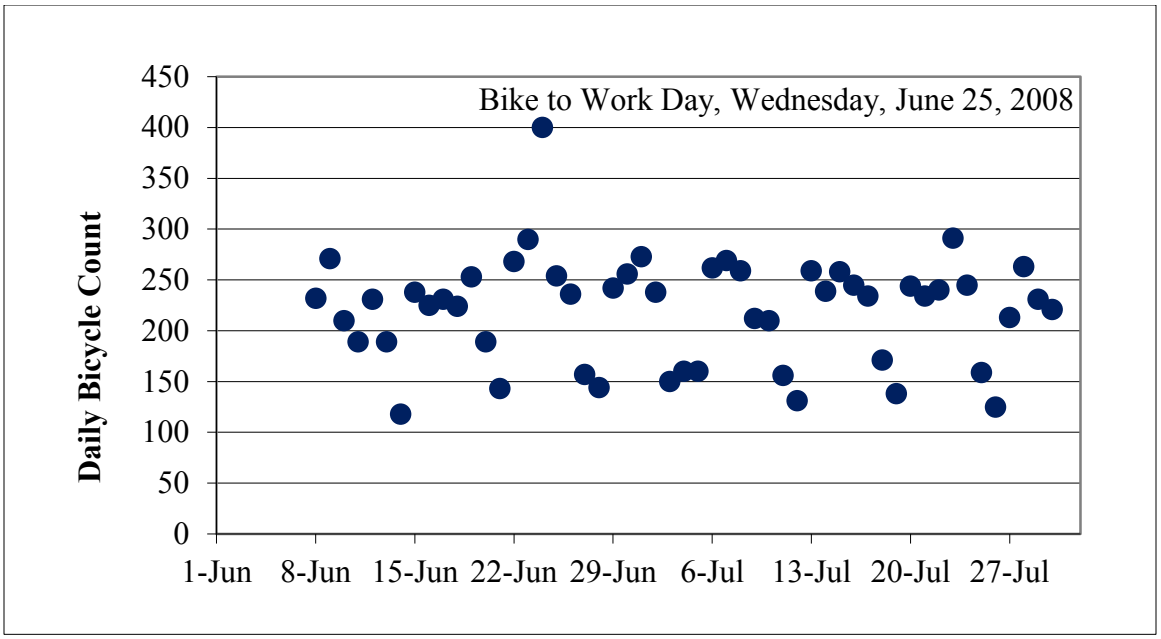

FIGURE 2 Example of daily bicycle counts in June and July 2008 for the station at Arapahoe Avenue and 38th Street in Boulder.

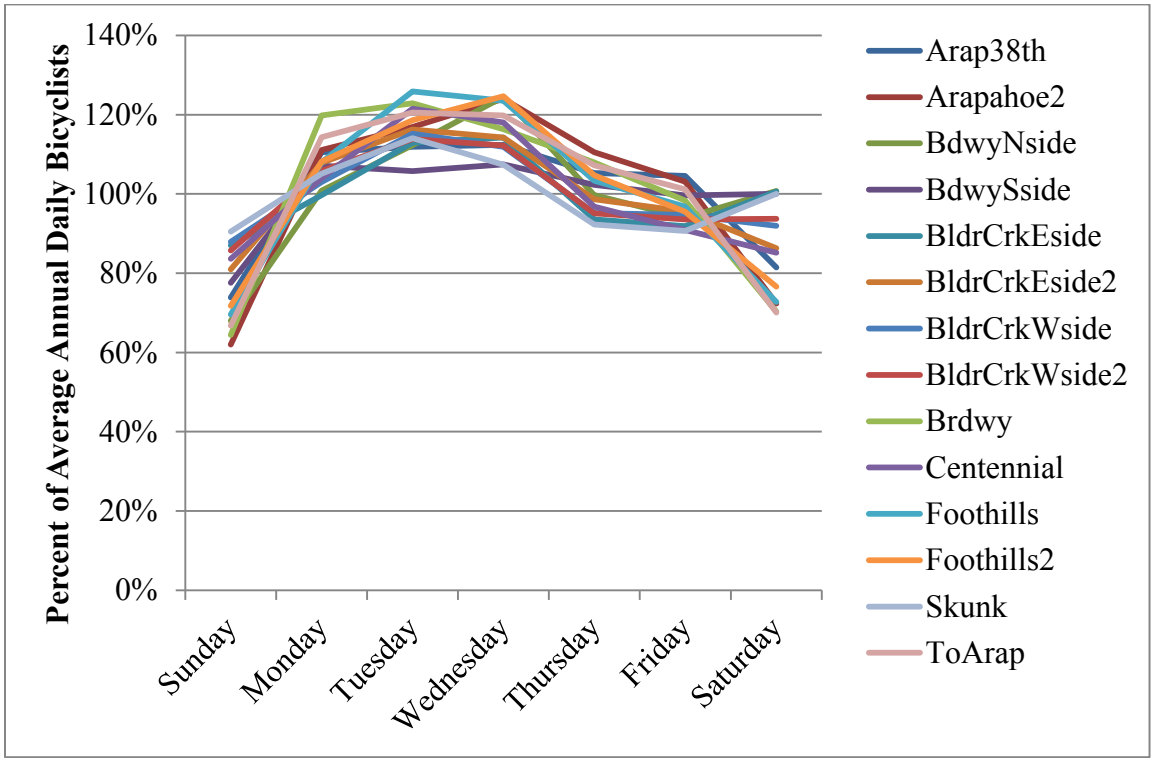

FIGURE 3 Percent of annual average daily bicyclists by day of the week for the 14 bicycle count stations within Boulder city limits for which 2010 data is available.

To determine if motor vehicle counts were significantly lower and bicycle counts were significantly higher on Bike to Work Day, 95% and 80% intervals around the average counts for the two months for Wednesdays alone and for Tuesdays, Wednesdays, and Thursdays together were computed, excluding Bike to Work Day. These intervals approximated the range in which 95% or 80% of the count data would be expected to fall, assuming that the daily traffic counts were roughly normally distributed. Additionally, the paired, one-tailed Student's *t*-test was used to test the hypothesis that bicycle counts on Bike to Work Day are significantly higher than average counts on Wednesdays in June and July and that motorized traffic counts are significantly lower.

RESULTS

Analyses of bicycle and motorist counts are discussed separately below.

Bicycle Counts

Increases in bicycle counts on Bike to Work Day are evident from Figure 4 which shows average bicycle volumes for Wednesdays in June and July for 2005, and 2007 through 2010. Sites with insufficient data were not included and days with partial counts were removed. Data were considered sufficient for a given site in a given year if a full 24 hours of counts during Bike to Work Day and at least six other Wednesdays in June and July were available in that year. The term, *n*, in Table 4 indicates the number of sites for each year with sufficient data. Since data was not available at every site for every year, comparing volumes over time would be misleading. Though the ratio of Bike to Work Day counts to average non-Bike to Work Day Wednesdays in June and July counts vary, on average Bike to Work Day bicycle counts are 2.1 times higher.

Of the 25 bicycle count stations during the five study years, there were 48 instances when there were sufficient counts in June and July to conduct the statistical tests described in the methods section. For the purposes of this paper, an "instance" is a set of count data for a given year at a given count station with sufficient available data. To have sufficient available data, an instance requires a full 24 hours of counts during Bike to Work Day and at least six other Wednesdays in June and July. Bike to Work Day counts were significantly higher than average Wednesday counts at the 95% confidence level for 46 of the 48 instances studied. At the 80% confidence level, Bike to Work Day bicycle counts were significantly higher in all of the instances (all sites and all years).

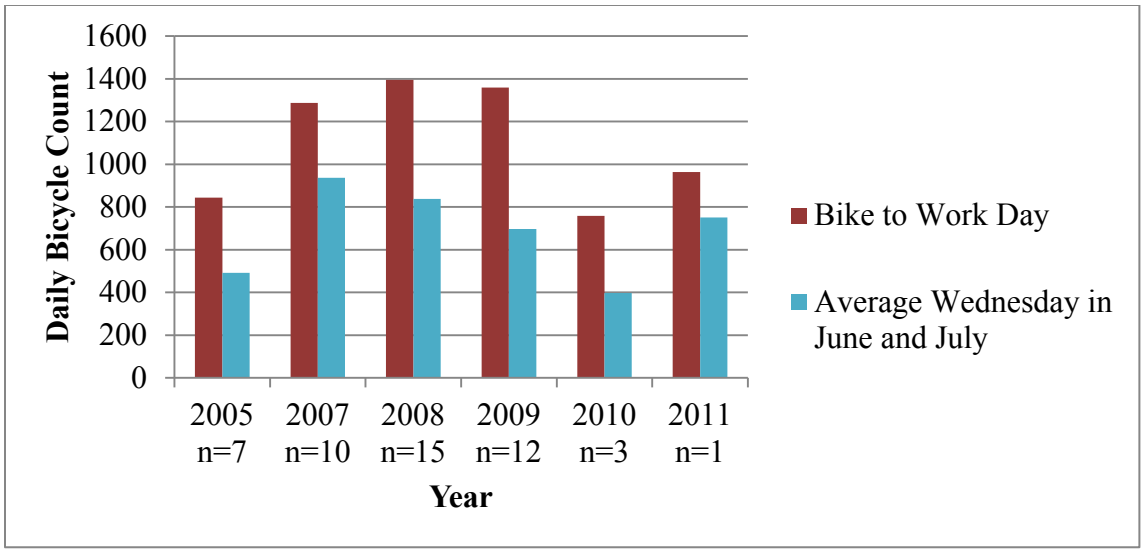

FIGURE 4 Average daily bicycle volumes for Wednesdays in June and July compared to total daily counts on Bike to Work Day averaged for all sites (n) with sufficient data.

Similarly results from the one-tailed, paired Student's t-test show that the differences between the daily bicycle counts on Bike to Work Day and the mean daily bicycle counts on Wednesdays are significantly higher than zero for the years studied (p-value < 0.0001). Figure 5 shows the distribution of the differences, showing that all of the differences are positive. The average difference between Bike to Work Day bicycle counts and average Wednesday counts is 491. The test results provide evidence that the counts on Bike to Work Day are significantly higher than zero with greater than 99% confidence.

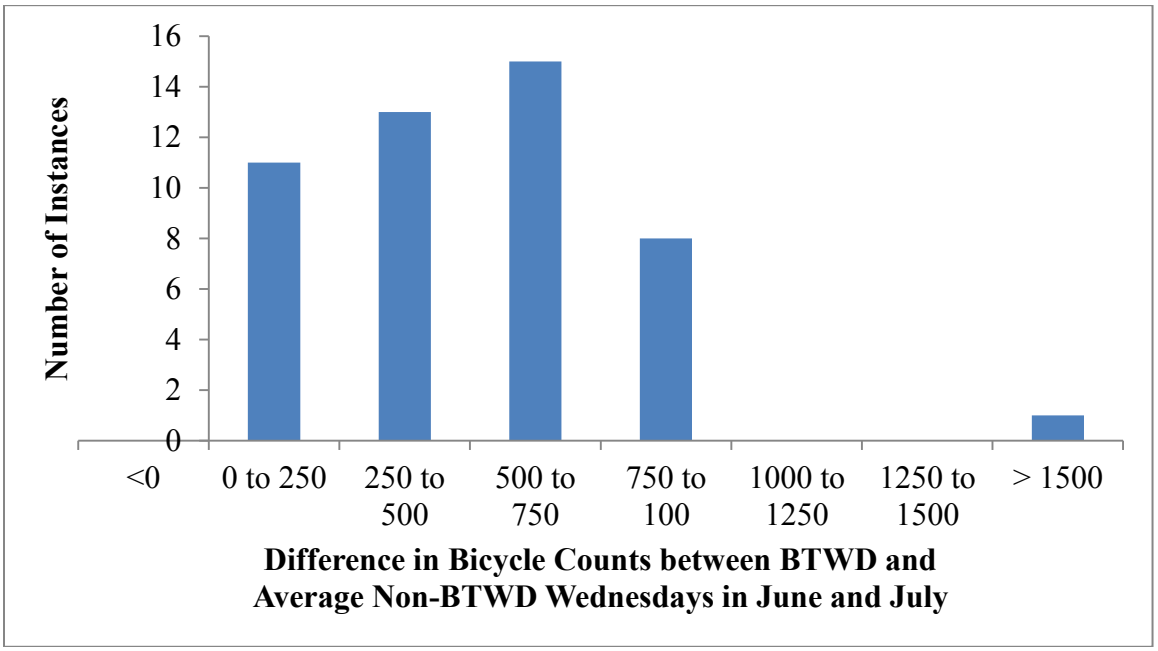

FIGURE 5 Histogram of differences between bicycle counts on Bike to Work Day and on average Wednesdays.

Motor Vehicle Counts

Changes in motor vehicle traffic on bicycle to work day are harder to observe as demonstrated by Figure 6, which shows the example of motor vehicle traffic in both directions on Canyon Blvd. at 28th Street during Bike to Work day in 2008. Compared to the clear increase in bicycle traffic on that day shown in Figure 2, the drop in motor vehicle traffic is slight. For this reason, statistical analysis is requisite in order to determine if the drop is more or less likely to be lower than typical weekdays.

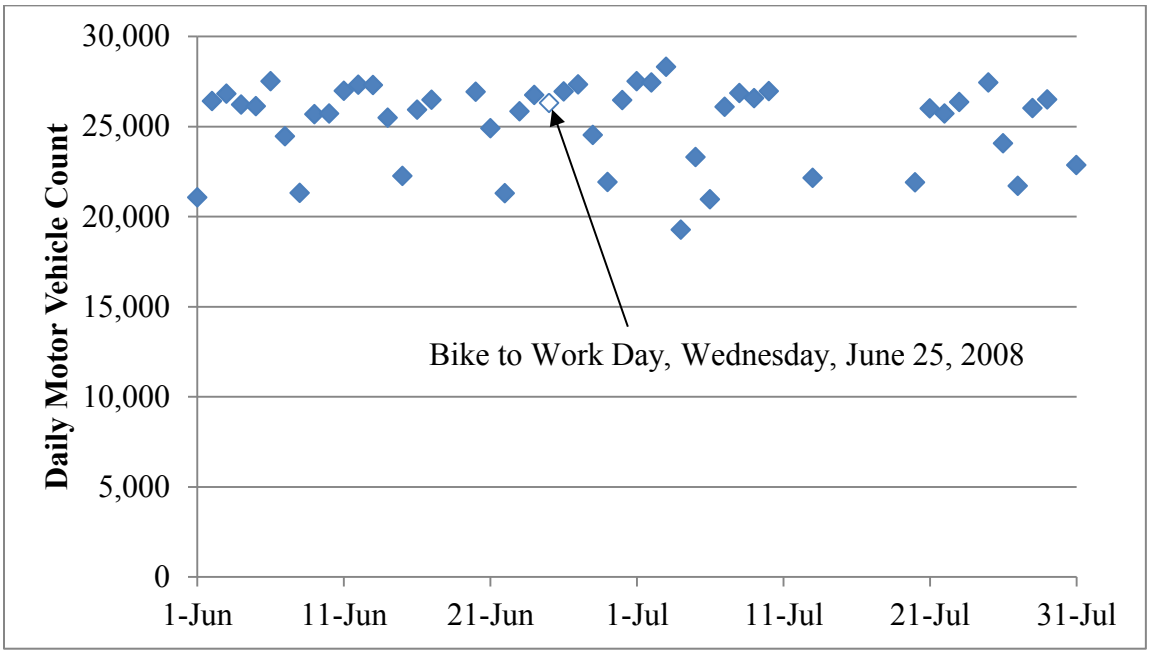

FIGURE 6 Example of daily motor vehicle counts in June and July 2008 for north and southbound traffic on Canyon Blvd. at 28th Street in Boulder.

Of the five motor vehicle count stations during the five study years, there were 16 instances when there were sufficient counts in June and July to conduct the statistical tests described in the methods section for Wednesdays only and 19 instances for Tuesdays, Wednesdays, and Thursdays. For each instance, the differences between typical weekday traffic and Bike to Work Day traffic are summarized in Table 1. The negative values on the table indicate a drop in motor vehicle counts compared to Bike to Work Day. Instances with significant drops or increases in traffic based on one-tailed 80% confidence intervals are indicated with asterisks and highlighted.

Compared to other average Wednesdays in June and July, all but two of the 16 instances (88%) studied show a decrease in counts for Bike to Work Day and five of these drops (31%) are significant at the 80% level. At the 95% confidence level, one instance (Northbound 28th St at Canyon Blvd. in 2010) showed a significant drop in traffic (-2.6%) compared to the average Wednesday. No instance showed a significant increase in traffic on Bike to Work Day compared to other average Wednesdays, and the two instances with insignificant increases were both at the station located outside of the city limits.

Compared to other average Tuesday, Wednesday, and Thursday in June and July, 68% of the 19 instances show decreases. Six of these drops (32%) are significant at the

80% level, and none are significant at the 95% level. Only one instance (Westbound US 36 at McCaslin in Superior in 2010) saw a significant increase in counts on Bike to Work Day (8.7%) at the 80% confidence level.

A paired, one-tailed Student's t-test was conducted on the average motorized traffic counts to test the null hypothesis that the difference between counts on Bike to Work Day and average Wednesdays is significantly greater than zero. The test found evidence that the alternate hypothesis, that the difference in counts is significantly less than zero, is true (p-value = 0.016). Thus, the results provide evidence that the drop in traffic counts on Bike to Work Day is significant at the 95% level. Figure 7 illustrates how the differences between Bike to Work Day and average Wednesday counts are distributed.

TABLE 1 Summary of percent change in motor vehicle count in the Boulder area for average June and July workdays compared to Bike to Work Day

Station	2005	2007	2008	2009	2010
FOR WEDNESDAYS ONLY					
Southbound 28th Street at Canyon Blvd.			-0.42%	-2.06%*	-1.20%
Northbound 28th Street at Canyon Blvd.			-2.64%*	-1.71%	**-2.74%***
Southbound 28th Street at Arapahoe			-0.05%	-1.77%	-0.16%
Westbound US 36 at McCaslin in Superior	-1.38%	0.80%	-2.07%*	-1.29%	
Eastbound US 36 at McCaslin in Superior	-0.27%	1.59%	-1.58%*		
FOR TUESDAYS, WEDNESDAYS, AND THURSDAYS					
Southbound 28th Street at Canyon Blvd.			0.09%	-2.10%*	-1.38%*
Northbound 28th Street at Canyon Blvd.			-1.94%	-1.77%*	-2.58%*
Southbound 28th Street at Arapahoe			0.31%	-1.64%	-0.44%
Westbound US 36 at McCaslin in Superior	-0.59%	0.79%	-2.30%*	-0.60%	0.97%
Eastbound US 36 at McCaslin in Superior	-0.02%	1.29%	-1.90%*	8.72%**	-0.54%

*Significant decrease on Bike to Work Day at 80% level **(Bold if also significant at the 95% level)**

**Significant increase on Bike to Work Day at the 80% level

A second paired, one-tailed Student's t-test was conducted on the average motorized traffic counts to test the null hypothesis that the difference between counts on Bike to Work Day and the average Tuesdays, Wednesdays, and Thursdays is greater than zero. The test found no evidence that the alternate hypothesis is true even at the 80% confidence level (p-value = 0.291). The average drop in counts on Bike to Work Day was 227.

Compared to both average Wednesdays and average Tuesdays, Wednesdays, and Thursdays, Bike to Work Day counts were lower on average (1.1% lower in the case of Wednesdays only, and 0.3% lower in the case of Tuesdays, Wednesdays, and Thursdays). This seems to be the right order of magnitude for the drop that would be expected if 491 (average increase in counts per bicycle count station) drivers chose instead to bicycle on that day. If we reduce the average Wednesday traffic count (26,839) by 491 we find a drop of about 2% in motor vehicle traffic would occur.

This is a simplistic estimate, given the complexities of travel choices. Some trips may be generated by Bike to Work Day events, while others may not be taken at all. For example, some cyclists who would have otherwise worked from home may be attracted to the event and some participants may bicycle out of their way to visit more than one breakfast station, while others may delay errands either by car or by bicycle in order to participate in the event. Also, some who cycle on Bike to Work Day may have ordinarily taken the bus, carpooled, or walked. The number of occupants in each motor vehicle counted was not included in this analysis. For these reasons, this simplistic approach does not capture all of the travel behaviors taking place on Bike to Work Day, but it does seem to indicate that at least the drops in motor vehicle traffic counts observed are of the approximate magnitude expected.

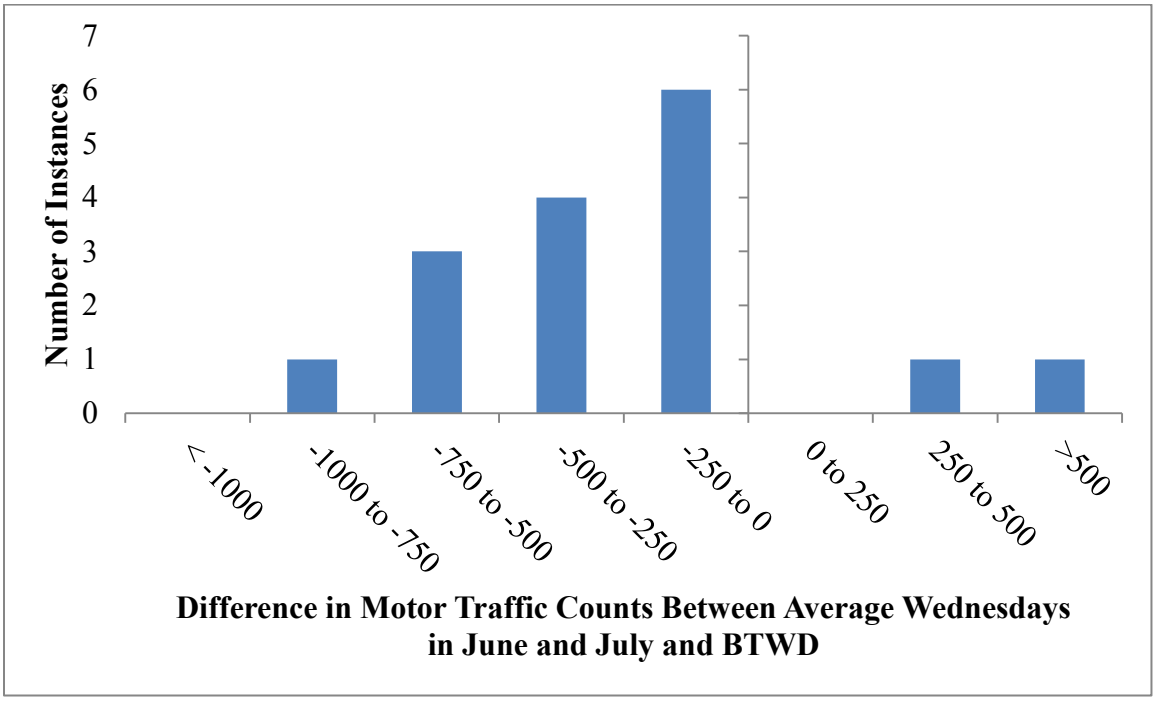

FIGURE 7 Histogram of differences between traffic counts on Bike to Work Day and counts on average Wednesdays for all 16 instances where data are available.

DISCUSSION

While a slight reduction in motor vehicle traffic can be observed in the data studied, one cannot conclude that this drop is necessarily caused by the Bike to Work Day event or by the high bicycle volumes. However some who would otherwise drive do choose to bicycle, and this behavior has been documented in surveys performed by the local metropolitan planning agency, which indicate that roughly 70% of Bike to Work Day participants drive alone when not cycling to work (*12, 13*).

If all those who drove on Bike to Work Day were unaware of the event, this might be an even better test. However, the extensive advertising and publicity that makes the even successful and encourages some to switch from driving to walking, also makes many drivers in the city aware of the event, which could potentially mean that some might choose to drive more expecting reduced traffic. Alternatively, some may choose to

drive less to avoid conflicts with cyclists. In either case, this aspect of the event makes it a slightly imperfect test.

The results reported here are for a one day event. If bicycling increased to these levels on a more regular basis, would the corresponding reduction in motor vehicle traffic observed on Bike to Work Day continue? One can only speculate. Additional roadway capacity would be made available by those who once commuted by motor vehicle and have since switched to bicycle commuting. This additional capacity might induce demand for more motor vehicle trips by others who previously chose not to travel at peak hour due to congestion. This phenomenon might be particularly visible in Boulder where roadways and intersections often operate near or at capacity during peak hours. For this reason, even successful efforts to encourage bicycle use may not lead to long-term reductions in motor vehicle traffic. This study simply shows that for a one day increase in bicycle commuting, corresponding reductions in motor vehicle traffic were observed.

Because Boulder is home to a large university and known as one of the most bicycle friendly cities in the country (*23*), some may question whether observed behavior would transfer to other locations. Boulder has a higher bicycle, pedestrian, and transit mode share than those observed in neighboring communities, but based on this one might expect the impact of Bike to Work Day events to be more diluted as those who would otherwise take transit or walk to work choose to bicycle on Bike to Work Day in addition to those who would otherwise drive. For this reason, larger drops in motor vehicle use might be observed in other communities, if a similar increase in bicycle commuting were to occur on a given day. Alternatively, communities without the extensive bicycling infrastructure present in the city of Boulder may not experience the participation in a bicycling event seen in Boulder, even if the same level of effort and advertising were employed. However, if the event were successful, despite the lack of infrastructure, these communities would likely also see a drop in motor vehicle traffic similar to what was observed in Boulder.

If a city chose to decrease roadway capacity for motorists and increase it for bicycles, would more choose to cycle? This cannot be answered with the evidence presented herein, but one can say that the traffic behavior observed on Bike to Work Day supports the hypothesis that longer term behavior changes could occur.

CONCLUSION

Bicycle counts on Bike to Work Day are clearly higher than on other workdays, and there is evidence of a corresponding drop in motorized traffic counts on Bike to Work Day. There is a consistent drop in the motorized traffic counts on Bike to Work Day with 13 of the 19 cases, about two-thirds, showing a decrease compared to similar average workdays in June and July. At the 80% confidence level, six of the 19 cases, about a third, showed a significant drop on Bike to Work Day. Only one of the 19 cases shows a significant increase in counts at the 80% confidence level.

Comparing Bike to Work Day motor vehicle traffic counts to average Wednesday counts using the one-tailed, paired t-tests provides evidence that the drop in traffic counts on Bike to Work Day is significant at the 95% confidence level, but the similar t-test with Tuesday, Wednesday, and Thursday counts does not show a significant drop.

With only 19 cases examined, the continuous motor vehicle count dataset for Boulder is not large enough to conclusively prove that total vehicle counts throughout the

city are significantly reduced on Bike to Work Day compared to the average summer work day. However, neither does this prove that there is not such a drop, and the general decrease in motorized counts and t-test results for Wednesdays provides evidence that a measurable drop in motor vehicle occurred at the locations studied.

This research shows that, for the cases studied, increased bicycle use on Bike to Work Day is associated with reduced motor vehicle use. This illustrates the potential for using bicycle trips to reduce motor vehicle traffic and thus to alleviate congestion, noise, air pollution and other problems related to motor vehicle use. For this reason, the topic should continue to be investigated. Further work should include a larger geographic area or more continuous motor vehicle count sites, as well as additional bicycle count sites. The results found in this study show that even with limited data, a drop in traffic counts can be observed.

ACKNOWLEDGEMENTS

The author is grateful for the help of Steve Abeyta at CDOT for providing traffic count data and Michael Gardner-Sweeney at the city of Boulder for providing traffic counts from the photo red light cameras and bicycle count data, with assistance from Jeff Bunker, Bob Major, and Joe Paulson. Additionally, Joe Cooper, Josh Sperling, Becky Shoag, Kurt Nordback, Landon Hilliard, Julie Norton, and Pat Noyes assisted in checking bicycle counter accuracy. Andrea Solis and Rachael Bronson at University of Colorado Denver and Sirisha Kothuri at Portland State University have also provided useful input on this project. Thanks also to CDOT, AAUW, WTS Colorado Chapter, the Association of Schools of Public Health and Centers for Disease Control and Prevention, FHWA's Eisenhower Transportation Fellowship Program, and National Science Foundation (IGERT Award No. DGE-0654378) for funding this work.

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