

CLOSING THE BICYCLING GENDER GAP:
THE RELATIONSHIP BETWEEN GENDER AND BICYCLING INFRASTRUCTURE IN
THE NATION'S LARGEST CITIES

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ABSTRACT

The percentage of trips taken by bicycle and the number of bicyclists in the U.S. has steadily increased in the past decade. Accounting for this increase are men ages 25 to 64. Nationwide trends indicate women accounting for 25 percent of bicyclists and 24 percent of the nation's bicycle trips. Cities like Portland, Oregon with high cycling quantities also have higher female cycling numbers. Studies in Portland show that women respond positively to on-street bicycle facilities with a buffer from automobile traffic. Northern European cities with separated infrastructure see upwards of 50 percent female ridership. These cities have created an environment that is receptive to bicycling, and in turn have more bicyclists and ultimately more women bicyclists. Infrastructure creates a streetscape to accommodate more bicyclists, and the type of infrastructure can serve as an undeniable indicator to the quantity of women bicycling.

This research examines the relationship between adults who bike to work and the quantity of lanes, routes, and paths in the 51 largest U.S. cities using data from the Alliance for Biking & Walking's 2010 and 2012 U.S. Bicycling and Walking Benchmarking Project. This research finds a strong relationship between male ridership and bike routes, while female ridership shows a stronger relationship to bike paths. Women's data shows a positive correlation between change in infrastructure and change in ridership over time.

Gaining quantitative understanding of the infrastructure that leads to increased perceived safety among women can inform new safety and design standards that can accommodate all types of bicyclists. Statistically analyzing bicycle commuting data creates significant findings to support anecdotal research of women's bicycling perceptions to create a link between infrastructure and gender. These findings will begin to shrink the gender gap in bicycling.

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INTRODUCTION

National trends in cycling over the past 20 years show steady increases in ridership. The National Household Travel Survey (NHTS) and the Nationwide Personal Transportation Survey (NPTS) show that the total number of bicycle trips from 1977 to 2009 nearly tripled. Of these bike trips, journeys by bicycle from one point to another, those for utilitarian purposes like shopping, work, public transportation connections, and recreational rides have increased from 43 to 52percent (Pucher, 2011). Accounting for this increase in utilitarian cycling are city dwellers between the ages of 16 and 24 with low car ownership. United States Department of Transportation (USDOT) data shows an overall increase in people bicycling, with the share of men’s bike trips accounting for 76 percent of all trips and the share of women’s bike trips accounting for 24 percent in 2009 (Figure 1; Pucher, 2011).

When discussing bicyclists, men account for 75 percent, and women have remained at or below 25 percent for the past decade. While both more men and women are bicycling and more trips are being made by bicycle, the share of women cycling as a portion of all cyclists is decreasing.

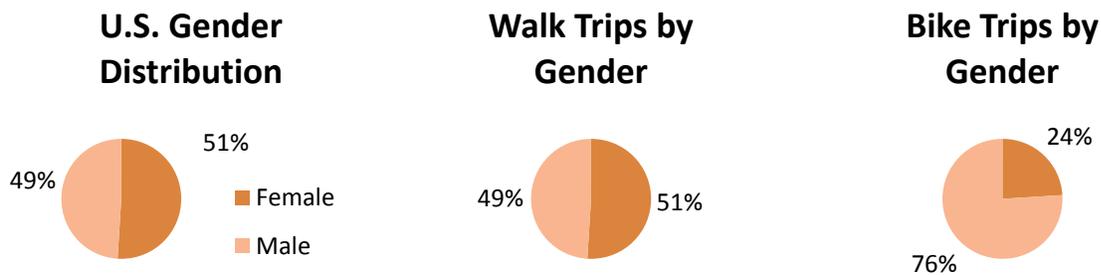


Figure 1: Gender distribution for walking and biking in 2009 (Alliance, 2012, p. 44).

There is nothing inherent in men that make bicycling more feasible (Garrard, 2003; Krizek, 2005; Emond, 2009; Pucher, 2011). NHTS data reveals that men are more likely than women to complete a trip by bicycle (0.66% vs. 0.25%), commute to work by bicycle (10.2% vs.

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6.24%), and bicycle for relaxation (2.14% vs. 0.79%). Women are more likely to bicycle to school as a student (1.2% vs. 0.58%), shop (2.64% vs. 1.11%), and visit friends and family (4.53% vs. 2.76%), indicating that they are receptive to recreational cycling (Krizek, 2005).

The factor that may contribute to these gender differences is the receptivity of the environment for women to bike. Garrard (2003) finds that this receptivity to cycling may not be translated properly into practice. For example, the perception of safety can be dependent on different types of bicycle facilities (Emond, 2009). Risky and unsafe circumstances affect women's decision to bike far more than men's (Garrard, 2003). Krizek (2005) hypothesizes that women bicycle less because "men are less affected by inferior cycling facilities" (p. 32). Although men experience approximately as much discomfort on average as women while bicycling mixed with heavier traffic, men are more likely to report that they will ride anyway, in contrast to women who indicate that they will not (Emond, 2009). Better understanding the relationship between a woman's decision to bike and available bicycle infrastructure is thus an important area to investigate.

Anecdotal evidence provides the majority of literature on women's bicycling preferences and barriers. This research will build on top of the existing qualitative data to provide statistical findings for the relationship between gender and bicycling infrastructure. This research takes advantage of the bicycle commuting data available to appeal to the larger body of research in gender and bicycling. Performing a quantitative analysis for nation's largest cities will provide a pulse of the country to begin to quantify this relationship between gender and bicycling infrastructure.

BACKGROUND

The differences between men's and women's transportation, lifestyle habits, and facility preferences can help to explain the gender gap in U.S. bicycling statistics.

The increase of women in white-collar professions and the growing level of female college graduates contribute to the slowly changing societal and economic roles of women (Crane, 2007; Rosenbloom, 2004). Gender is linked to aspects of employment such as income, household roles, proximity to work, and type of profession which influences travel choice (McGuckin, 1999; Rosenbloom, 2004). Women work closer to home, link shorter journeys together to create one trip, and have a "lack of discretionary time" due to incorporating additional work, home, and family responsibilities into their commutes (Crane, 2007; McGuckin, 1999; Garrard, 2008, p. 57). Aggregate women's travel patterns reveal that women have shorter work commute trips and link together multiple shorter trips, traveling an overall shorter mean distance than men (Figure 2; Garrard, 2008; Krizek, 2005). When making the decision to bike a woman has to take into consideration her roles and responsibilities as a provider and a mother (Emond, 2009; Rosenbloom, 2004).

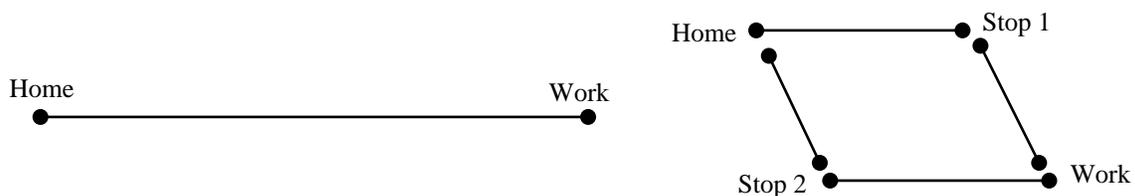


Figure 2: Trip length and chaining differences between men and women.

Women make more trips on behalf of the household than men, partaking in complex trip chaining over multiple stops with cargo and passengers (McGuckin, 1999; Krizek, 2005). Trip chaining becomes essential to fulfill her many roles (McGuckin, 1999; Handy, 2004). When possible for women to complete household chores by bicycle, the rate of cycling for household trips increases (Krizek, 2005). However, a personal vehicle allows for flexibility and safety when

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catering to household needs and provides a private, protected environment women perceive as safe (Clifton, 2004; Elvik, 2009; Handy, 2004). These patterns suggest that the trip's purpose greatly affects travel by bicycle (Krizek, 2005).

Women's natural traits of heightened perceived risk and need for safety create additional barriers to cycling that men do not equally encounter. Risk aversion, an increased need for safety, and accidents all influence women's travel mode and route choice (Baker, 2009; Rosenbloom, 2004; Harris, 2006; Howard, 2001). These influences affect a woman's level of comfort while bicycling, and thus her decision to bike (Emond, 2009; Furth, 2012). "Women tend to judge negative outcomes associated with risky behaviors as both more likely and more severe; they also indicate a lower likelihood of engaging in these risky behaviors and judge the activities as less enjoyable than do men (assuming that the negative outcomes do not occur)" (Harris, 2006, p. 54). Women are more likely to perceive more negative consequences on the road and identify negatives in the physical environment during their commute such as pavement condition (Emond, 2009; Harris, 2006; Krizek, 2005). Because of these differences towards safety and risk, women are more likely to be in the 'No-Way-No-How' bicyclist classification group than in the 'Enthusied and Confident' and 'Interested but Concerned' groups (Dill, 2012a; Geller, 2006). If women have the opportunity to bike in an environment "that both is, and is perceived to be, safe and supportive" there is a greater chance of success to get more women bicycling (Baker, 2009; Garrard, 2003, p. 213).

Cyclists generally choose their routes based on a variety of factors including time, safety, shortness, and directness (Howard, 2001). Women show a stronger preference for safer forms of cycling infrastructure and less motor vehicle traffic (Krizek, 2005, Pucher, 2010). Women value and will travel extra minutes to use these specific facilities with separated infrastructure from

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traffic, paved shoulders, and lighted paths (Emond, 2009; Krizek, 2005). Dill (2012b) finds that 94% of women across age groups vs. 64% of men were more likely to agree that a cycle track made their commute safer. But the study also revealed that 94% of women were equally as likely as 87% of men to agree that a buffered lane made their commute safer. Garrard (2008) finds that Australian women cycle a shorter mean distance (1.5 km) and prefer off-road paths; men travel a longer mean distance (1.64 km) on a variety of infrastructure. Dill (2012b) notes that these gender preference findings will help the city achieve its goals of higher ridership. In countries with high ridership, and thus high female ridership, the greater availability of separated facilities may be the contributing factors to increased levels of women cycling (Garrard, 2012).

The knowledge behind women's usage patterns, route decisions, and preference for different cycling facilities provides information for planners and policy officials (Krizek, 2005). By expanding the bicycling network to indirectly ease the feelings of safety and risk, planners can improve bicycling conditions to make bicycling more appealing for all users (Xing, 2008; Winters, 2010). Some bicycling research highlights the effect of infrastructure on different bicycling audiences and how to produce a cycling environment suitable for a range of safety preferences, encouraging "targeted policies" in transportation (Krizek, 2005, p. 38). The connection between policy and bicycle infrastructure can produce a positive effect on the safety of the bicycling infrastructure (Jacobsen, 2003).

The national increase in bicycling results in a lopsided increase in male bicyclists. Women's household and employment responsibilities in combination with a natural awareness of risk and safety make bicycling a less feasible transportation option. Understanding transportation habits and preferences for each gender can help reorient U.S. bicycle planning efforts to create a network of infrastructure to accommodate cyclists regardless of gender.

METHODS

The purpose of this research is to determine the relationship between the quality of bicycle infrastructure and level of female ridership to test the hypothesis that there exists a relationship between types of infrastructure and ridership by gender.

The Alliance for Biking & Walking, a nonprofit organization with the mission to strengthen and unite state/province and local bicycle and pedestrian advocacy organizations, has developed a benchmarking report to measure efforts of bicycling and walking. As part of the U.S. Bicycling and Walking Benchmarking Project, the Alliance for Biking & Walking collected data on levels of bicycling and walking, safety, policies, education and encouragement, grassroots advocacy, influences on bicycling and walking, public health benefits, and economic benefits of biking and walking in all 50 states and the 51 most-populated U.S cities. This data created the U.S. Bicycling and Walking Benchmarking Report for 2010 and 2012.

Two sets of data were part of the 2010 and 2012 Benchmarking Reports: ridership by gender and by state and miles of bicycle infrastructure by type. The ridership data actually came from the American Community Survey (ACS) table B08006, administered by the U.S. Census Bureau and aggregated to major cities and state geographies. Ridership numbers in the 2012 Benchmarking Report are from ACS 2009; ridership numbers in the 2010 Report are from ACS 2007. The unit of study for ridership is the quantity of men and women bicyclists as a percentage of the total city population.

The infrastructure data was collected through three surveys conducted by the Benchmarking Project Team with City, State, and advocacy organizations. Surveys were used because bicycle infrastructure data is not readily accessible from national sources. Interviews were conducted in 2008/2009 for the 2010 Report and 2010/2011 for the 2012 Report. Miles of

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bike facilities per square mile of city area are the primary unit of analysis, also called infrastructure density. Bicycle facility types included are defined by the Alliance for Biking & Walking as:



- Lanes- infrastructure denotes with on-street striped lane markings;
- Routes-streets marked with signed bike routes;
- Paths- multiuse and bicycle paths; and
- Total infrastructure- the sum of lanes, routes, and paths for each city.

Using these two sets of data and examining the relationship between bicycle infrastructure and gender, it can be possible to get a better understanding of how women make the decision to bike relative to the infrastructure that exists.

Three types of analyses were completed.

- Analysis 1 examines the relationship between infrastructure type and gender.
- Analysis 2 examines the validity of the relationship between infrastructure types and gender.
- Analysis 3 examines the change over time between infrastructure and ridership by gender.

The purpose of Analysis 1 is to determine the relationship between women's ridership and the quantity of lanes, routes, paths, and total infrastructure. A pairwise correlation analysis

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tests the strength and directionality of the relationship between number of riders and infrastructure. Separate pairwise analyses were conducted for men and women. The pairwise correlation requires two variables, bicycle infrastructure density and either men or women cyclists as a portion of each city's population. The significance (sig) and observations (obs) commands were added to the pairwise correlation to produce a correlation coefficient (R) and a p-value which indicate the strength and validity of the relationship. Analysis 1 resulted in 16 pairwise matrices.

The purpose of Analysis 2 is to determine the significance of the relationship between ridership by gender and infrastructure levels identified as "good" by comparing the mean value for ridership in cities with good infrastructure and cities without good infrastructure. Analysis 2 uses a two-group mean-comparison t-test. This test evaluates whether significant differences exist in the mean values of ridership in cities with good infrastructure and cities without good infrastructure. Cities reporting densities of lanes, routes, and paths higher than or equal to the weighted average of the 51-city sample are coded with a "1" to indicate good infrastructure. Cities reporting densities of infrastructure less than the weighted average are coded with a "0" to indicate they are without good infrastructure. The t-test provides a difference of means, a t-value, and a p-value. Analysis 2 resulted in 16 t-tests.

The purpose of Analysis 3 is to examine the relationship between the change in number of men and women riding bicycles and the change in density of facilities. Change was calculated for each gender's ridership by finding the difference between bicyclists as a percent of the city's population in 2012 and in 2010. This difference in ridership becomes one new variable for Analysis 3. Change was calculated for total infrastructure by finding the difference between total infrastructure density in 2012 and in 2010. This difference in infrastructure becomes another new

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variable. The resulting R values and p-values show the strength and significance of the relationship between changes in infrastructure and changes in ridership by gender. Analysis 3 results in two pairwise matrices.

Cities with zero women bicyclists were eliminated in each analysis because of the low likelihood of absolutely no women bicycling. Infrastructure observations were eliminated with a z-test. Any infrastructure values above or below three standard deviations from the mean were eliminated in Analysis 1 and Analysis 3 because the pairwise correlation is highly sensitive to outliers. Very few cities reported infrastructure values outside of this margin. Eliminating outliers assists in finding relationships amongst the majority of cities included in the sample and eliminates the risk of extremely misreported data.

FINDINGS

Results from the analyses will be presented in two categories: facility type and ridership by gender, and changes over time to infrastructure levels and ridership by gender. This section will identify the findings from each analysis by gender to develop an overall finding of the relationship between ridership by gender and miles of infrastructure in the 51 largest cities in the U.S.

Facility type and ridership by gender

Analysis 1

Analysis 1 finds the relationship between bicycle ridership by gender and infrastructure density. This analysis does not indicate causation. Table 1 shows the determining values from the pairwise correlation completed in Analysis 1.

Variable 1	Variable 2	R value		p-value		Cities	
		2010	2012	2010	2012	2010	2012
<i>Women's ridership</i>	Total infrastructure	0.4926	0.4158	0.0007	0.0037	44	47
	Bike lanes	0.3654	0.3448	0.016	0.0176	43	47
	Bike routes	0.3441	0.2937	0.0344	0.0658	38	40
	Bike paths	0.3321	0.359	0.0316	0.0143	42	46
<i>Men's ridership</i>	Total infrastructure	0.6045	0.5249	0	0.0001	47	51
	Bike lanes	0.519	0.399	0.0002	0.0037	46	51
	Bike routes	0.3847	0.4933	0.0142	0.0007	40	44
	Bike paths	0.2958	0.3958	0.0459	0.0049	46	49

Table 1: Analysis 1 findings

A moderate strength positive correlation exists between the women's cycling population and total infrastructure from the data in the 2010 Benchmarking Report. A strong positive correlation exists between men's ridership and total infrastructure with 2010 Benchmarking Report data. These relationships decrease slightly in strength with the data from the 2012 Report.

Individual correlations for infrastructure types show differences in the relationships between men and women. Correlations for types of infrastructure using 2010 Benchmarking Report data show bike lanes as the driving variable for each gender's positive correlation to infrastructure. Bike lanes result in the strongest correlation, followed by routes and then paths when analyzing the correlation strength for both genders using 2010 Benchmarking Report data (Table 1). When calculating correlations for infrastructure types using 2012 Benchmarking Report data paths become the driving variable in the overall relationship between infrastructure and women's ridership. Bike lanes maintain a moderate positive correlation and routes decrease in correlation strength for women's ridership. As ridership increases paths become the most influential factor in the relationship between women's bicycle commute data and infrastructure. The driving variable for the positive correlation between men's ridership and infrastructure shifts from bike lanes to bike routes. Bike lanes decrease in correlation strength while bike paths increased in correlation strength for men bicycle commuters.

Analysis 1 for both the 2010 and 2012 Benchmarking Report data indicates a relationship between infrastructure and both male and female bicyclists, male cyclists more strongly related than female. When examining specific infrastructure and the relationship to bicyclists by gender, the 2010 Report data indicate that there is a significant relationship between bike lanes for both genders. The 2012 Report data indicates a stronger relationship between men and bike routes and a stronger relationship between women and bike paths. This analysis exposes clear separations between the relationship of bicycle commuting by gender and infrastructure.

Analysis 2

Analysis 2 demonstrates the validity of the relationship between ridership and “good” infrastructure, where “good” infrastructure indicates quantities above the weighted average for the 51 study cities in the Benchmarking Reports. Table 2 shows the determining values for each t-test completed in Analysis 2.

Variable 1	Variable 2	Good Cities / Total Cities		t-value		p-value	
		2010	2012	2010	2012	2010	2012
<i>Women's ridership</i>	Good infrastructure	21/48	21/47	0.0003	0.0001	-3.9327	-4.1836
	Good lanes	22/48	18/47	0.1749	0.0004	-1.3778	-3.8052
	Good routes	19/48	20/47	0.8941	0.8576	0.1338	0.1805
	Good paths	25/48	19/47	0.0565	0.0007	-1.9565	-3.6316
<i>Men's ridership</i>	Good infrastructure	21/51	21/51	0	0	-5.6364	-5.2025
	Good lanes	22/51	18/51	0.0101	0.0001	-2.6757	-4.1217
	Good routes	19/51	20/51	0.9218	0.2729	-0.00986	-1.1089
	Good paths	26/51	21/51	0.0414	0.0002	-2.095	-4.0649

Table 2: Analysis 2 findings

The t-test measuring male and female ridership and good infrastructure using data from the 2010 and 2012 Benchmarking Reports result in statistically significant differences between the mean ridership for cities with and without good infrastructure. Cities with good infrastructure

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have a statistically significantly higher mean ridership in women and in men than cities without good infrastructure.

Breaking down good infrastructure into good lanes, routes, and paths with 2010 Report data shows the driving variables for the relationship between women's ridership and good infrastructure. Bike paths provide the only statistically significant finding to indicate a difference between women's ridership in cities with and without good infrastructure when analyzing the 2010 Benchmarking Report data. Cities with good paths have a statistically significant higher mean ridership than cities without good bike paths. The relationship between ridership and cities with good lanes and cities with good routes did not produce statistically significant results.

Data from the 2012 Benchmarking Report produced stronger results for t-tests with good lanes, routes, and paths. Cities with good bike lanes and good bike paths have statistically significant higher mean ridership. Cities with good routes did not produce statistically significant results to support a difference in the mean ridership between cities with good routes and without good routes. These findings are consistent with the findings using 2012 Report data in Analysis 1, indicating the weakest correlation between ridership and bike routes.

The analysis for good lanes and good paths results in a statistically significant difference for men's mean ridership in cities with and without good lanes and paths using data from 2010 and 2012 Benchmarking Reports. Analysis 2 did not produce statistically significant results to support a difference in the mean ridership between cities with and without good bike routes for either year of the Benchmarking Report data (Table 2).

Analysis 2 findings result in a significant difference in mean ridership between cities with and without good infrastructure for both genders using 2010 and 2012 Benchmarking Report data. Women's ridership is statistically significantly higher in cities with good paths found using

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2010 Report data, and good paths and good lanes found using 2012 Report data. Men's ridership is statistically significantly higher in cities with good lanes and good paths in findings from both 2010 and 2012 Report data. Analysis 2 highlight shifts in the mean ridership values for men in cities with good routes.

Changes over time to infrastructure levels and ridership

Analysis 3

Analysis 3 shows the relationship between the change in ridership by gender and the change in infrastructure between the 2010 and 2012 Benchmarking Reports. Table 3 identifies values from each correlation which indicate the strength of the relationship between changes in the two variables. This analysis finds if change in infrastructure relates to changes in bicycle ridership by gender.

Variable 1	Variable 2	R value	p-value	Observations
<i>Change in women's ridership</i>	Change in total infrastructure	0.2286	0.1265	46
<i>Change in men's ridership</i>	Change in total infrastructure	0.0773	0.6095	46

Table 3: Analysis 3 findings

Analysis 3 shows a positive correlation between change in the women's bicycling population and infrastructure. This finding confirms the finding from Analysis 1 which shows a relationship between the quantity of women that commute to work by bike and the quantity of total infrastructure in a city. This finding also confirms the finding from Analysis 2 which shows that mean ridership is statistically significantly higher in cities with good infrastructure. There is virtually no correlation between the change in men's ridership and the change in total infrastructure because of the high p-value and small correlation coefficient.

The analyses were completed to find if a relationship exists between ridership by gender and bicycle infrastructure, how that relationship changes with specific types of infrastructure, and if the relationship between infrastructure and ridership by gender changes over time. The

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results indicate a relationship between ridership in the 51 study cities and infrastructure. Four main findings of this study are:

- There is a positive relationship between bicycling and total infrastructure, and the strength of the relationship changes between men and women.
- Both genders maintain a significant and positive relationship with bike lanes; however, men have a significant relationship with bike routes while women have a significant relationship with bike paths.
- Cities with good infrastructure see higher mean ridership from both sexes. Specifically cities with good lanes and good paths have statistically significant higher mean ridership for both sexes.
- The relationship between change in ridership and change in infrastructure is positive and statistically significant for women. There is no relationship for men.

DISCUSSION

Findings show a relationship between bicycle infrastructure and people biking to work, and show different relationships between gender and specific types of infrastructure. Findings will be discussed as they relate to existing literature and the stated hypotheses. The hypotheses are that there exists a relationship between infrastructure and ridership by gender; the relationship between men bicyclists and infrastructure will be stronger due to women's societal responsibilities, roles, and safety and risk concerns; a stronger relationship will form between women's ridership and separated infrastructure; and there exists a relationship between change in infrastructure and change in ridership by gender.

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Findings of a relationship between infrastructure and ridership by gender support women's and men's considerations taken when commuting by bicycle. Correlations are weaker between female ridership and infrastructure than male ridership and infrastructure. Reasons for this may be because a woman's decision to bike is not primarily based on a modeling concept of directness or time, but rather an ecological approach which combines factors in the physical environment, the social environment, and her individual concerns (Emond, 2009). Women are more in tune with the safety, quality, and riskiness of their environment. The slightest negative in the physical environment can dissuade a woman from biking (Krizek, 2005). The weaker relationship between women bicyclists and infrastructure shows that women are more concerned with the qualitative conditions of the infrastructure, rather than it simply being available for use. Men are more likely to perceive fewer negative consequences in their physical environment than women, and will bike in a 'risky' environment anyways (Harris, 2006). The stronger correlation between male bicyclists and infrastructure shows that men will bike regardless of the placement, condition, or connectivity of the bicycle facilities provided.

Findings support women's preferences for infrastructure with less automobile traffic. The level of comfort while bicycling is an important influence on a woman's decision to bike (Emond, 2009). Findings show the strongest relationships between women bicyclists and lanes and paths. Both lanes and paths provide the traits women seek in a safe bicycling environment—separate from traffic and good pavement quality. Both bike lanes and bike paths, as defined by the Alliance for Biking & Walking, provide separation through lane markings or a path system solely for bicycle or foot traffic without automobile traffic. Dill's (2012b) study finds that when given the opportunity to describe how either a cycle track or a buffered bike lane affects a woman's daily bike commute, she was more likely to agree that the cycle track made her

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commute safer. A cycle track provides complete separation from automobile traffic which supports the finding that women show a preference for safer infrastructure and less motor vehicle traffic.

Findings for the relationship between male ridership and bike routes prove noteworthy. The lack of significant findings for routes proves to be more significant than thought. Men bicyclists show strong relationships to lanes and routes. Routes mix bicycle and automobile traffic and have no additional infrastructure improvements to provide a safer area for bicyclists. Neighborhood roads are often designated as bicycle routes because no construction is required, the only indication being a sign for automobile traffic. Routes can be designated as an afterthought to form a connected bicycle network. The relationship between male ridership and routes reinforces the literature that states that men select routes based on directness. Men are more likely to report that they will ride in environments with heavier traffic that women classify as uncomfortable, leading more men to bike in locations with routes or simply neighborhood roads.

Findings support the literature that indicates that men are more likely to decide to bike in heavy traffic or unsafe environments while women will bike if the environment permits them to do so safely. The findings show there is a relationship between female ridership and infrastructure changes over time. More infrastructure creates the perception of a safe bicycling environment, leading more people to bike (Dill, 2003). According to Jacobsen (2003), with higher ridership comes safety in numbers; the greater the quantity of people biking the safer the environment will be. Safety in numbers and an increase in infrastructure create additional awareness around bicycles that may create an environment women perceive as safe over a period of time (Jacobsen, 2003).

Limitations

The Alliance of Biking & Walking Benchmarking Reports for 2010 and 2012 are the most comprehensive source of data for bicycle infrastructure quantities. This study takes advantage of the limited bicyclist count data available to prepare a statistical analysis to relate bicycle ridership and infrastructure. However, certain limitations exist:

- The nation's largest cities were the focus of this analysis which does not offer a representative correlation between bicycling infrastructure and women riders in the most general sense. Examining a sample size greater than 51 would make the findings more transferrable. However, examining large cities provide an opportunity to take the pulse of the country with regards to relating bicycling and infrastructure.
- The bicycle ridership numbers by gender only examines the working population, eliminating a substantial portion of the bicycling population that identify as recreational bicyclists, pleasure bicyclists, or simply those that bike for reasons other than commuting to and from work. Examining the working population can provide a glimpse into quantifying the relationship between infrastructure and bicyclists.
- The 2012 Benchmarking Report identifies reporting errors for 2010 infrastructure quantity data. While the 2010 reporting errors were accounted for in this analysis, there is currently no means of reporting errors in the 2012 infrastructure quantities. Cities without infrastructure quantities to report for the 2010 Benchmarking Report maintained quantities from the 2007 Benchmarking Report. Cities without infrastructure quantities to report for the 2012 Benchmarking Report maintained quantities from the 2010 Benchmarking Report.

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- The data provided on ridership and infrastructure is strictly quantitative, not taking into account the qualitative aspects of the bicycle infrastructure such as accessibility, availability, connectivity, level of bicycle friendliness in each city, safety of area surrounding the bicycle infrastructure, and overall acceptance of bicycling as a mode of transportation. All of these factors and more can sway a woman's social-environmental and individual factors that contribute to her decision to bike.

The analytical approach for this research also has limitations:

- The pairwise correlation is highly susceptible to outliers skewing the results. To mitigate this issue outliers were eliminated. A larger sample size would help mitigate the effects of extreme outliers by providing more observations throughout the range of data.
- Recoding the data in Analysis 2 separates the observations into two groups for a new way of analyzing the data. More levels of infrastructure groups can strengthen the analysis beyond cities with and without good infrastructure.
- The STATA analyses employed do not provide any conclusion for causation, merely correlation. This is the ever-present issue when studying infrastructure's effects on travel behavior because of the difficulty in quantifying before and after travel behavior and associating it entirely due to the fact of infrastructure improvements.

RECOMMENDATIONS

The findings from the analyses indicate that there is a relationship between types of infrastructure and cyclists by gender. This research identifies a disconnect in current bicycle planning approaches and the goals of increasing ridership to close the bicycling gender gap. The following recommendations for a more inclusive National bicyclist classification system,

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comprehensive approaches to increasing ridership, and annual data collection for bicycle infrastructure can assist in closing the bicycling gender gap.

The FHWA bicyclist classification system can incorporate factors beyond level of comfort to create a sliding scale model for classifying bicyclists. Presently, the Federal Highway Administration (FHWA) uses the bicycle compatibility index to classify cyclists in three stages (advanced, basic, and children) based on their level of comfort biking in traffic. The BCI takes one aspect of female bicyclists (their likelihood to be less comfortable riding with traffic), and uses it as the main point of classification. This results in female bicyclists more likely to be classified as inexperienced. However, one's level of comfort while in traffic provides a one-sided approach to portraying one's bicycling experience. A bicyclist classification system to lead planning efforts should include trip purpose, safety concerns, and regularity of transporting cargo and passengers. All bicyclists, regardless of gender, will then be able to accurately find where they fit in the sliding scale, and planning efforts can begin to accommodate the variety of bicyclists. Furth's (2012) research on labeling a route's level of traffic stress based on the most stressful portion opens the doors for a user-based bicycle network classification system. The same results can be achieved by creating a more inclusive bicyclist classification system, so plans can be developed for a route or city's most vulnerable user. Instead of using a user-based bicycle network planners can develop a bicycle network based on a user-based bicyclist classification system. This user-based bicyclist classification system can encourage nationwide policies to plan for a specific level of user as the standard. Reframing the structure of the transportation system around user perspective can elicit greater gender sensitivity in bicycle planning and higher ridership numbers.

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A comprehensive approach to increasing bicycle ridership benefits users who make the decision to bike based on social and individual factors instead of just the physical biking environment. There is a moderate-strength relationship between women's bicycling data and infrastructure and a slightly higher relationship for men's bicycling data, so there can be multiple factors that ultimately play into each individual's decision to bike. Addressing ridership from both hard approaches, infrastructure, and soft approaches, individualized marketing campaigns, can sway bicyclists that are almost ready to make the decision to bike. A comprehensive approach encourages exhaustion of current bicycling conditions; the infrastructure in place can be more thoroughly utilized while getting more bicyclists on the roads without making a large capital investment in new infrastructure to encourage more ridership.

This research shows that infrastructure can be a decisive factor in eliciting male and female bicyclists to commute to work. A standardized and perhaps mandatory statewide infrastructure and bicyclist quantity reporting system can help planners properly understand infrastructure's impacts. This system can inform future research and offer opportunities to research measurable results of increases in infrastructure and funding dedicated to bicycle infrastructure. Infrastructure is not the only piece of the bicycling pie, but it is an intensive and expensive factor. A state or city-based reporting system can provide an inventory of existing conditions and offer quantifiable opportunities to research impacts and benefits of improving a location's bicycle network. Not only can an inventory legitimize a city's efforts to become more bicycle friendly, it can highlight the effort to standardize bicycling data and develop bicycling as a valid mode of transportation. The approach to use data to connect gender and the built environment can then inform research of the relationship to increase ridership on a state or even national level.

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Bridging the gender gap in bicycling can go beyond getting more women on bicycles. These recommendations can inform a bicycling system that encourages even the most timid of bicyclists. Closing the gender gap goes beyond the distinction of male and female; it begins to pull together the factors to inform the discussion of developing a means of increasing ridership that reaches the non-bicyclists.

CONCLUSION

The analyses and research reveal that there is a moderate to strong relationship between the level of women's bicycle commutes to work and infrastructure in the 51 largest cities in the US. This quantitative and statistically supported research confirms qualitative and anecdotal evidence of gender preferences for infrastructure while bicycling. While women's ridership proved relationships to bike lanes and bike paths, men's ridership showed stronger relationships overall to total infrastructure and more specifically to bike lanes and bike routes.

Learning women's bicycle travel preferences invites policy and program development, comprehensive approaches, and flexible rider classifications to go beyond the generalized term of "bicyclist," and begin to understand how planners and communities can create an environment to serve specific portions of the population to increase ridership and benefit the community as a whole.

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