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Multinomial logistic regression to estimate and predict perceptions of bicycle and transportation infrastructure in a sprawling metropolitan area

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ABSTRACT

Background Inactivity levels in the USA are considered a critical public-health issue. Promoting physical activity through active transportation may prove effective to increase activity levels. The purpose of this study was to understand perceptions and likelihood of using various bicycle infrastructures for transportation by Las Vegas residents.

Methods A survey was developed and administered ($n = 457$). Multinomial regression was used to create predictions to determine which infrastructures were perceived as safe and most likely to be used for transportation; frequencies were analyzed.

Results The infrastructure chosen least often (2.2%) had the least amount of distance separating bikers from vehicles, and the least amount of protection. The type most likely to be used (27.6%) contained the most signage and significant separation from vehicles. The infrastructure least likely perceived to be adequate for biker safety was a shared bus/bike lane with 19.4% agreeing this was safe. Probabilities revealed differences in infrastructure preferences based on demographic characteristics.

Conclusions In order to increase active transportation rates effectively, residents' perceptions of safety and infrastructure preferences should be considered. Results from this study showed that respondents had many safety concerns with the current bicycling infrastructure in Las Vegas and provided ideas for future infrastructure investments and related policies.

Keywords communities, environment, physical activity

Introduction

Physical inactivity in the USA is one of the leading causes of death, contributing to multiple chronic diseases and shortened life expectancy. Nationwide, ∼50% of the population self-reports that they participate in enough aerobic physical activity, which is 150 min of moderate physical activity per week.[1] This is insufficient to meet the *2008 Physical Activity Guidelines for Americans*. However, a sample that represented national norms, using physical activity levels that were measured objectively, found that only 9.6% actually met the guidelines.[2] At this point, the level of inactivity of Americans has reached an alarming level, and has become a critical public health issue.

For decades, attempts to increase levels of physical activity focussed on changing behaviours at the individual level, targeting one person at a time. While these efforts may be effective in the short term, studies have shown that such interventions have low rates of maintenance after the interventions have ceased.[3,4] For this reason, the promotion of physical activity by means of active transportation may prove effective as a means

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to increase activity levels. Active transportation incorporates physical activity into daily routines, such as walking to and from work or errands, enabling the attainment of minutes of physical activity without the conscious decision, and a high level of commitment required for recreational physical activity.

In an attempt to increase physical activity levels, more recent efforts have involved approaches at a population level. The Community Preventive Services Task Force—a group of independent, unpaid, public health and prevention experts that provide evidence-based findings and recommendations on a number of topics—recommended the use of environmental and policy approaches to increase physical activity, specifically, policies on street-scale urban-design land use.[5] Evidence shows that street-scale elements—such as the availability of sidewalks, bicycling facilities, proximity to transit stops[6] as well as adequate lighting[7] are associated with increased minutes of physical activity. As such, understanding street-scale factors that may result in an increase in active transportation rates may be one way to increase rates of physical activity effectively.

The metropolitan area around Las Vegas, NV is sprawling, similar to many metropolitan areas developed in the post-automobile era. Although this region consists of over 2 million residents, it lacks a central urban core that most traditional—that is, older—cities have; this results in housing and other land uses (retail, office and commercial) being spread over long distances. Given the amount of urban sprawl in Las Vegas, active transportation that incorporates the use of bicycling would enable residents to travel longer distances in more convenient amounts of time by means of either active transport alone or in combination with public transportation.

The purpose of this study was to understand perceptions and likelihood of using various types of bicycle infrastructures for transportation purposes by Las Vegas residents.

Methodology

A survey questionnaire was developed to capture preferences about seven alternative configurations for bike-lanes. Figure 1 shows each of the seven configurations. The survey included socioeconomic characteristics as well as other questions related to infrastructure, biking habits and the use of transit. The survey was administered in person and online; it targeted bus riders, bike riders and drivers of personal vehicles. Trained surveyors approached residents at bus stops, on bus routes, and at local businesses and common areas surrounding major transit corridors. An identical survey was distributed online through local biking and non-biking member lists. In addition, a snowball methodology for sampling was used, by which respondents were asked to share the survey link with local friends and relatives. The survey included Likert scale, multiple choice, open-ended and demographic questions; it took ~10 min to complete, and the respondents were not compensated. This study design was given exempt status from the Internal Review Board (IRB) of the University of Nevada, Las Vegas (UNLV).

A discrete choice model was estimated to determine significant attributes and socioeconomic characteristics that are likely to influence preferences about the various infrastructure configurations in the survey. Probit and multinomial Logit models were estimated to determine the best model specification. A multinomial rather than a binary model is required because the number of available choices, infrastructure configurations, were seven. A multinomial Logit model is an extension of multiple regression modelling, where the dependent variable is discrete instead of continuous, enabling the modeling of discrete outcomes. In particular, we were interested in characterizing the probability of individual choices conditioned to the values of the attributes and socioeconomic characteristics. The estimation requires defining the reference category with which the results will be compared. Thus, the infrastructure choice which most resembled the dominant infrastructure type in the Las Vegas metropolitan area was used as the reference category (non-painted 5-ft bike lane). The model can be used to estimate choice probabilities. In addition, the model provides information about the relative importance of the explanatory variables (significant attributes and socioeconomic characteristics).

Results

Descriptive analysis

Overall, 457 surveys were completed in their entirety. Of the respondents, 67.8% reported using a personal vehicle as their primary mode of transportation, 26.2% reported using public transit (bus) and 6.0% reported using a bicycle. Four respondents reported that walking was their primary mode of transportation; however, they were removed from analysis due to the small sample size.

The respondents were asked a series of questions regarding safety as well as the likelihood they would use one or more of seven different options for bicycling infrastructures. In addition, they were asked to choose one option that they would most likely use if they used bicycling for transportation. The most frequently chosen infrastructure the respondents were most likely to use was option B (27.8%), a non-painted 8-ft bicycle lane with a 3-ft buffer and reflective posts on a non-major roadway. The least chosen infrastructure was Option A (2.0%), a non-painted 5-ft bicycle lane with no buffer on a non-major roadway. Respondents perceived Option C as the safest and having the most adequate signage. Figure 1 shows each of the seven configurations along with the respondents'

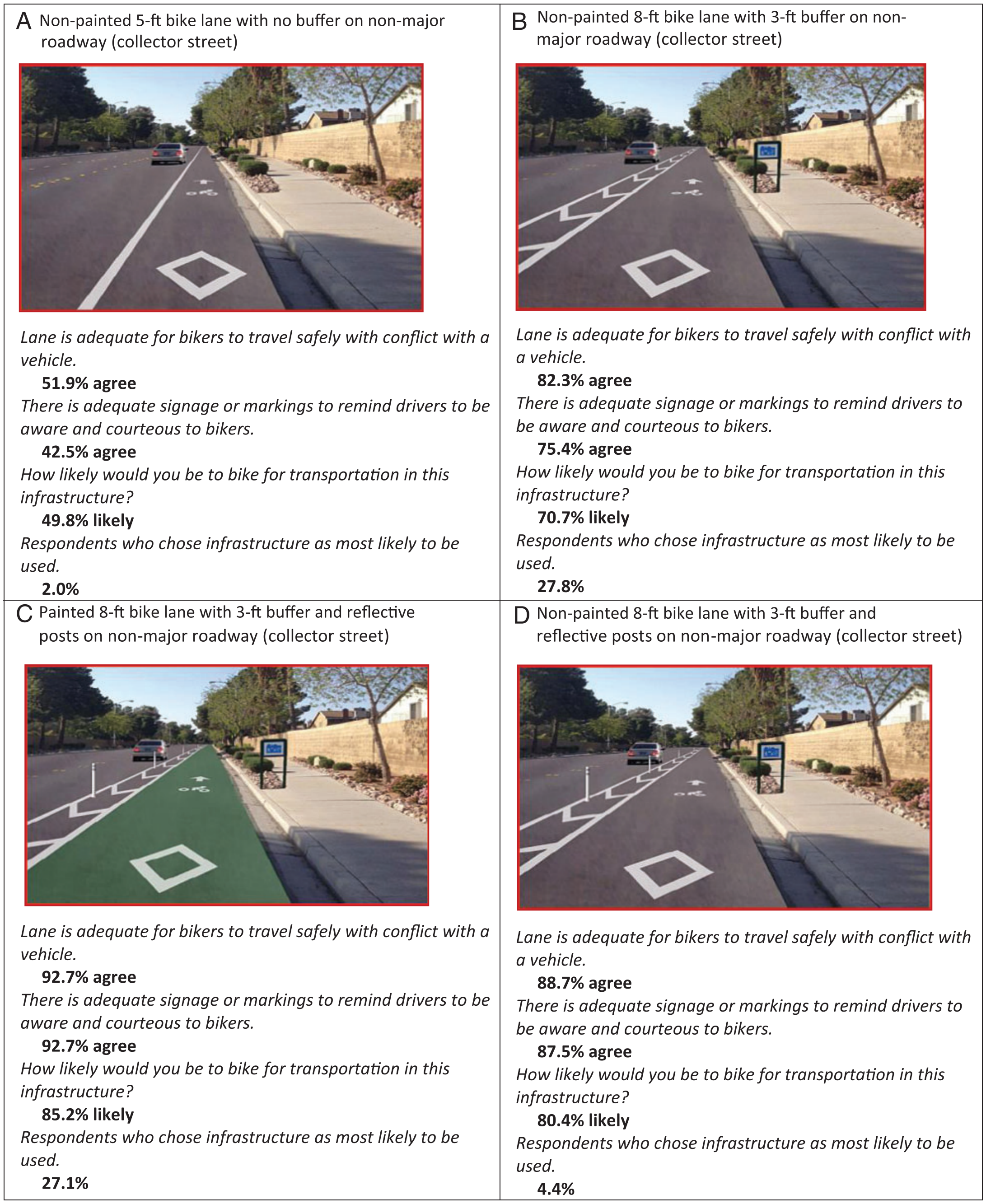


Fig. 1 Each infrastructure option, perceptions of safety and likelihood of use for each, and frequencies which that option was chosen as the infrastructure type most likely to be utilized.

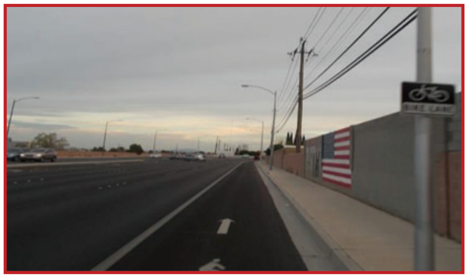
perceptions of safety and likelihood of use, and the frequency in which each configuration was chosen as the most preferred alternative.

Multinomial logistic regression

First, a linear model was run on the response as a function of the predictors to ensure that there were no multicollinearity issues; only predictors with variance inflation factors (VIF) <2 were included in this model (VIF age: 1.342; VIF gender: 1.069; VIF how_often_ public transport: 1.354; VIF automobiles_household: 1.208; VIF bike_daily: 1.116; VIF income: 1.517).

Table 1 provides the list of categorical socioeconomic characteristics as well as the list of choices available to the participants in the survey. In addition, age information was collected with a minimum, maximum, average and standard deviation

E Non-painted 8-ft bike lane with no buffer on major roadway (arterial street)

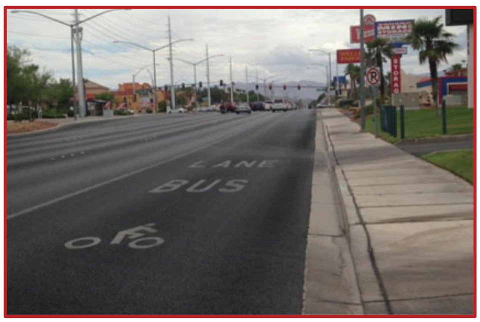


Lane is adequate for bikers to travel safely with conflict with a vehicle.
22.5% agree
There is adequate signage or markings to remind drivers to be aware and courteous to bikers.
19.0% agree
How likely would you be to bike for transportation in this infrastructure?
24.2% likely
Respondents who chose infrastructure as most likely to be used.
6.1%

F Off road trail

Lane is adequate for bikers to travel safely with conflict with a vehicle.
75.4% agree
There is adequate signage or markings to remind drivers to be aware and courteous to bikers.
74.8% agree
How likely would you be to bike for transportation in this infrastructure?
77.8% likely
Respondents who chose infrastructure as most likely to be used.
19.0%

G Shared bus and bike lane on major roadway (arterial street)



Lane is adequate for bikers to travel safely with conflict with a vehicle.
19.4% agree
There is adequate signage or markings to remind drivers to be aware and courteous to bikers.
20.7% agree
How likely would you be to bike for transportation in this infrastructure?
21.3% likely
Respondents who chose infrastructure as most likely to be used.
13.6%

Fig. 1 *Continued*

of 16, 77, 37.78, 13.13, respectively. The dependent variable had one value observed in 422 subpopulations, and the most frequently chosen infrastructure was B (27.8%). Of the respondents, 69.8% reported they did not bike daily; 59.5% were male, 34.4% reported a yearly income less than $30 000, and 37.4% reported that they never used public transportation. Regarding the model fitting information, the χ^2 ratio tests had a value of 296.689 (P-value < 0.000) (AIC criterion 1396; Hannan-Quinn criterion: 1463), indicating good model fit. In addition, acceptable values were obtained from pseudo r^2 (Cox and Snell: 0.478; Nagelkerke: 0.495).

Logit models provided better goodness of fit compared with the general Probit models. This is likely because the unobserved factors are not normally distributed; the goodness-of-fit indicators and power of classification of the best Probit model are lower than those obtained by the best Logit model.

Table 1 Categorical variables

	Category	N	*Marginal percentage (%)*
Infrastructure choice	A	9	2.0
	B	127	27.8
	C	124	27.1
	D	20	4.4
	E	28	6.1
	F	87	19.0
	G	62	13.6
Bike daily	Yes bike trips daily	138	30.2
	No bike trips daily	319	69.8
Gender	Male	272	59.5
	Female	185	40.5
Income	Less than $30 000	157	34.4
	$30 000–49 999	59	12.9
	$50 000–69 999	77	16.8
	$70 000–89 999	43	9.4
	$90 000–150 000	79	17.3
	Greater than 150 000	42	9.2
How often do you use public transportation?	Very often	62	13.6
	Often	50	10.9
	Rarely	74	16.2
	Very rarely	100	21.9
	Never	171	37.4
Ethnicity	American Indian or Alaska Native	2	0.4
	Asian	37	8.1
	Black or African American	40	8.8
	Hispanic, Latino or Spanish origin	57	12.5
	Native Hawaiian or other Pacific Islander	11	2.4
	White	290	63.7
	Some other race	18	4.0

The best Probit model resulted in the following: χ^2 ratio tests: 9.40822 (P-value $<$0.00905798) and the goodness-of-fit indicators and power of classification with a AIC criterion: 1547, Hannan-Quinn criterion: 1566, χ^2 ratio tests: 14.1785 (P-value $<$0.0277), and power of classification: 34.1%.

Table 2 indicates that the power of the logistic multinomial model was suitable, as it correctly classified 45.7% of the known observations and could be expected to project future estimates. Table 3 shows the multinomial logistic regression model for all coefficients. The reference category for the model was Infrastructure A, as it best represented the most common infrastructure in the Las Vegas metropolitan area.

When examining the odds ratio, people who reported biking daily compared with those who do not bike daily were most likely to choose Infrastructure D over A. People who reported an income of $70 000–$89 999 were most likely to choose Infrastructure B, and people who reported using public transit very often were most likely to choose Infrastructure D. Those who reported using public transit rarely, compared with those who reported never using it, had increased odds of 0.17 of choosing Infrastructure B over A.

Regarding the predictions, the above-mentioned parameters were used to estimate the future value of the possibilities of occurrence. The probabilities were examined of both males and females of the oldest and youngest age categories reported by respondents, the mean age and those who reported biking daily and not biking daily. The oldest age group was most likely to fall in the highest income category, and had at least two vehicles in the household. The youngest age category was most likely to fall into the lowest income category, and had no vehicles in the household. The mean age was 38 years, and the median income was $50 000–$69 999. Thus, these categories were used to estimate probabilities.

Table 2 Power of classification

Observed	*Predicted*							
	A	*B*	*C*	*D*	*E*	*F*	*G*	*Percent correct*
A	0	4	5	0	0	0	0	0.0%
B	0	95	14	0	1	5	12	74.8%
C	0	25	90	0	0	8	1	72.6%
D	0	8	11	0	0	1	0	0.0%
E	0	21	2	0	0	3	2	0.0%
F	0	22	50	0	1	12	2	13.8%
G	0	42	4	0	0	4	12	19.4%
Overall percentage	0.0%	47.5%	38.5%	0.0%	0.4%	7.2%	6.3%	45.7%

Table 3 Results of a multinomial logistic regression model reflecting the choice of infrastructure

	Infrastructure choice																	
	B			*C*			*D*			*E*			*F*			*G*		
	B	*SE*	*Exp (B)*	*B*	*SE*	*Exp (B)*	*B*	*SE*	*Exp (B)*	*B*	*SE*	*Exp (B)*	*B*	*SE*	*Exp (B)*	*B*	*SE*	*Exp (B)*
Intercept	4.730*	2.276		4.433*	2.328		3.206	2.572		3.165	2.466		3.586	2.354		4.136*	2.352	
Age	0.033	0.032	1.034	−0.009	0.032	0.991	0.012	0.037	1.012	0.042	0.035	1.043	0.011	0.032	1.011	0.037	0.033	1.038
Number vehicles in household	−0.407	0.323	0.666	−0.313	0.313	0.731	−0.346	0.364	0.707	−0.726	0.400	0.484	−0.384	0.320	0.681	−0.476	0.342	0.621
Bike daily[a]	−0.988	0.822	0.372	−2.413*	0.823	0.090	−1.824*	0.950	0.161	−0.963	0.903	0.382	−2.576*	0.843	0.076	−1.894*	0.857	0.150
Gender[b]	−1.167	0.888	0.311	−0.607	0.878	0.545	−0.609	0.982	0.544	−0.590	0.984	0.554	−0.704	0.888	0.495	−1.150	0.912	0.317
Less than $30 000[c]	−0.883	1.358	0.413	0.623	1.427	1.864	0.155	1.554	1.168	−1.124	1.513	0.325	0.697	1.461	2.008	−1.186	1.437	0.306
$30 000–$49 999[c]	−0.403	1.548	0.668	1.153	1.605	3.168	0.410	1.758	1.507	−0.120	1.650	0.887	1.442	1.634	4.229	−0.106	1.603	0.899
$50 000–$69 999[c]	−0.289	1.320	0.749	−0.004	1.408	0.996	−1.589	1.780	0.204	−0.830	1.456	0.436	0.044	1.448	1.045	−0.310	1.371	0.734
$70 000–$89 999[c]	17.383*	0.571	3.541E7	17.251*	0.887	3.105E7	16.671*	1.347	1.739E7	17.278*	0.825	3.189E7	16.888*	1.058	2.159E7	18.323	0.000	9.072E7
$90 000–150 000[c]	0.536	1.503	1.709	0.342	1.629	1.408	0.121	1.787	1.129	0.371	1.578	1.450	1.962	1.606	7.113	0.482	1.547	1.619
Public transit—very often[d]	−4.878*	1.572	0.008	−0.396	1.205	0.673	−2.421*	1.467	0.089	−19.575	3040.751	3.153E-9	−1.269	1.240	0.281	−4.180*	1.601	0.015
Public transit—often[d]	−1.883	1.416	0.152	0.659	1.380	1.933	0.144	1.482	1.155	−18.076	2869.592	1.411E-8	0.531	1.396	1.700	−2.755	1.709	0.064
Public transit—rarely[d]	−1.796*	1.017	0.166	−1.053	1.055	0.349	−1.044	1.164	0.352	−1.028	1.087	0.358	−0.684	1.043	0.504	−1.166	1.046	0.312
Public transit—very rarely[d]	0.044	1.282	1.045	0.535	1.301	1.707	−16.970	2423.646	4.268E-8	−0.034	1.358	0.966	0.394	1.309	1.483	−0.103	1.312	0.902

Model fitting information. AIC criterion: 1396; Hannan-Quinn criterion: 1463; −2 Log Likelihood: 1312.

[a]Reference category: no bike trips daily.

[b]Reference category: females.

[c]Reference category: greater than $150 000.

[d]Reference category: public transit—never.

*P-value ≤ 0.05, SE = standard error.

A female 18 years of age who did not bike daily, had an income less than $30 000, used public transit often, and did not have a vehicle in her household was more likely to choose Infrastructure A than the other infrastructure types. A female with the same characteristics who does bike daily was more likely to choose C, D and F over Infrastructure A. In contrast, a male 18 years of age who did not bike daily, had an income less than $30 000, used public transit often, and did not have a vehicle in the household was more likely to choose C over A in 52% of the cases. A male with the same characteristics who did bike daily was more likely to choose B, C, D and F over A.

A male 38 years of age who reported biking daily and had an income between $50 000 and $69 999, used public transit rarely, and had one vehicle in his household was more likely to choose B, E and G over Infrastructure A; a male with the same characteristics who did not bike daily was more likely to choose B over A in 58% of the cases. A female 38 years of age who reported biking daily and had an income between $50 000 and $69 999, used public transit rarely, and had one vehicle in the household was more likely to choose B and E over Infrastructure A. Females with the above characteristics who did not bike daily were more likely to choose A over all other infrastructures.

A male or female 77 years of age who reported biking daily, had an income between $90 000 and $150 000, used public transit very rarely, and had two vehicles in the household were more likely to choose B, C, E, F and G over infrastructure A. A female with the same characteristics who did not bike daily was more likely to choose B, E and G over A; males of the same characteristics who did not bike daily were more likely to choose B, E, F and G over A.

Discussion

Main finding of this study

Results of this study reveal that respondents were more likely to use biking infrastructures that provide adequate signage and space separation from vehicles. These findings provide guidance and design concepts for retrofitting as well as future infrastructure investments and related policies in the Las Vegas metropolitan area.

What is already known on this topic

Land-use policies for street-scale urban design have been shown to be effective at increasing the rates of physical activity. Specific street-scale factors also have been associated with increased rates of active transportation. Given the sprawling design of the metropolitan area of Las Vegas, Nevada, the use of a bicycle by itself or a bicycle in combination with public transportation would best enable a convenient commute time.

If policy-makers and public health professionals are to be successful at increasing active transportation through bicycle travel, it is imperative to understand what types of infrastructures that the residents perceive as safe and report being likely to use.

What this study adds

This study sampled various transit users to estimate safety and likelihood of use of seven different bicycle infrastructures in the Las Vegas metropolitan area. The infrastructure type that was chosen the least by respondents as the most likely to be used (2.0%) contained the least amount of space and protection from vehicles. Correspondingly, only 51.9% agreed that the bike lane was adequate enough to provide safety, and 42.5% thought there was adequate signage. Unfortunately, this simple, striped 5-ft bike lane resembles most bicycling infrastructures currently in the Las Vegas metropolitan area. The infrastructure type least likely perceived as adequate for biker safety was the shared bus/bike lane, with 19.4% of respondents in agreement. This infrastructure type is relatively rare in the USA, and is more common in the UK.[8] The safety and satisfaction of such lanes are understudied, and it should be examined in more detail before any large-scale implementation, specifically since the results in this study indicate that they were not preferred by many nor perceived as safe.

The infrastructure option that was rated the highest on all measures was a painted 8-ft bike lane with a 3-ft buffer and reflective posts. Of the seven options, this infrastructure contained the most signage by means of green paint on the lane in the roadway as well as reflector posts to remind drivers not to enter the lane. It provided a significant amount of space for the bicyclist to travel. This finding seems to indicate that survey respondents would be most likely to travel by bicycle for active transportation if they perceive safe separation from vehicles.

Probabilities revealed differences in infrastructure preferences based on (i) gender and (ii) whether or not individuals reported biking daily. All respondents who reported biking daily, regardless of age category or gender, chose at least one other infrastructure that offered more protection from vehicles than Infrastructure A. It is possible that prior biking experience may have shaped preferences towards the infrastructures that offered more space or protection from vehicles.

There was a small gender difference in the youngest and median age categories with females who did not bike daily; they were more likely to choose Infrastructure A than was any other. This is surprising, as Infrastructure A offered less protection from vehicles. Furthermore, past research found that females were more likely to prefer separate paths.[9,10]

Limitations of this study

This study is not without limitations. About 60% of respondents were male compared with ~50% of the residents in the Las Vegas metropolitan area. In addition, most of the respondents reported using a personal vehicle for their primary mode of transportation. The surveyors made numerous attempts to target and collect survey data from residents who used a bicycle as their primary mode of transportation, but they found this population difficult to locate. This is not surprising, given that the US Census Bureau[11] estimated that only 0.4% of Las Vegas residents use a bicycle when commuting to work. The power of the model classification is low, and a large part of this is provided by categories B and C. However, it is important to point out that understanding perceptions of those who are not current bicycle commuters likely is most useful in attracting new users and increasing the overall number of active commuters.

Estimates of the parameters for some categories are very large as a consequence of the data. However, all estimates and odds ratios are consistent with each other, and have appropriate standard error values.[12,13] That is, we have bias in the estimation.

With the nationwide epidemic of inactivity and associated health effects, increasing activity levels through active transportation is one potential resolution. To do so, it is imperative that policy-makers, public health professionals and urban planners work together to create infrastructure changes, and adequately design new infrastructures that are most likely to be utilized and attract new active transportation users.

Funding

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