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DOI
10.1177/03611981221117821

Publication date
2023

Document Version
Final published version

Published in
Transportation Research Record

Citation (APA)
Jahanshahi, D., Costello, S. B., Dirks, K. N., Chowdhury, S., & van Wee, B. (2023). Understanding Perceptions of Cycling Infrastructure Provision and its Role in Cycling Equity. *Transportation Research Record*, *2677*(3), 820-835. https://doi.org/10.1177/03611981221117821

Research Article

TRR
JOURNAL OF THE TRANSPORTATION RESEARCH BOARD

Transportation Research Record
2023, Vol. 2677(3) 820–835

DOI: 10.1177/03611981221117821
journals.sagepub.com/home/trr
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Understanding Perceptions of Cycling Infrastructure Provision and its Role in Cycling Equity

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Abstract

Ensuring equity is considered in all types of decision making, including with respect to cycling provision, is important. Studies have investigated equity in relation to provision of cycling infrastructure and facilities. However, identifying other factors that need consideration in cycling equity is important. This study explored the impact of cycling infrastructure provision on individual perceptions of cycling infrastructure in relation to sociodemographic characteristics in Auckland, New Zealand. The results indicated that bicycle lane availability did not significantly influence perceptions of cycling infrastructure; however, ethnicity and whether a person was a regular cyclist did. Among noncyclists and potential cyclists, ethnicity was the only factor found to significantly influence perceptions of cycling infrastructure. Māori, the indigenous people of New Zealand, and Pacific Islanders rated the provision of cycling infrastructure higher than others for the same level of bicycle infrastructure in their community. Whereas Māori had the highest percentage of potential cyclists among all ethnicities, Pacific Islanders had the highest percentage of noncyclists (64.9%), the lowest percentage of potential cyclists, and one of the lowest percentages of regular cyclists. The study showed that cycling provision perceptions were more affected by factors like ethnicity, education, and bicycle user type than objective measures of bicycle infrastructure. Following the capabilities approach of justice, this study suggests that equitable provision of cycling infrastructure may not lead to an equitable cycling environment. To achieve this, interpersonal and intrapersonal indicators such as ethnicity and community-related factors must also be considered to encourage and empower all population groups to cycle.

Keywords

bicycles, equity (justice), transportation and society, equity in transportation, perception

Cycling brings with it a range of health, environmental, and societal advantages over other modes of transport (*1–4*). As a result, the promotion of cycling has become a key strategy adopted in many countries for reducing the reliance on private vehicles for mobility. However, little attention has been paid to how resources allocated to cycling infrastructure and other cycling initiatives can be distributed fairly and equitably in the sense that the benefits as well as the costs are shared equally across all members of society (*5*).

In cycling equity analysis specifically, studies have been carried out on the interaction between the provision of bicycle infrastructure, the place of residence and employment, and the income levels of both advantaged and disadvantaged population groups (*6–11*). The majority of such studies have focused on access to bicycle infrastructure or cycling facilities, including bicycle sharing systems (BSS) and dockless bicycle sharing systems (DBSS), or access to destinations by bicycle (*12–15*). Such studies have shown that disadvantaged populations,

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those living in lower-income neighborhoods, those from minority population groups, women, the elderly, and immigrants, usually have lower access to bicycle infrastructure and facilities, and experience lower bicycle usage rates (*16*). Because studies have primarily focused on the fair distribution of cycling infrastructure among neighborhoods, the solution has necessarily been the provision of more or better infrastructure to disadvantaged population groups. However, more consideration is needed of aspects beyond traditional infrastructure provision, to include education, level of awareness about the benefits of cycling, cycling skills, and other sociocultural factors, for example, the demand for social and family cycling and the need to access places of importance for specific communities (*16–19*) to help address inequity.

The capabilities approach of justice argues that focusing only on the distribution of resources to provide equity can be misleading (*20*, *21*). For example, cycling-related perceptions can vary among individuals, be context-specific, and can be influenced by multiple factors, such as differences in general income and development levels of the society, as well as geographical, cultural, and religious factors (*4*, *16*), aspects that tend to be largely ignored (*19*). Other sociodemographic characteristics can also influence people's perceptions about cycling. For example, young people tend to be more cost-aware than older groups, parents more influenced by the needs of their children, and women more risk-averse than men (*22–26*). Different communities can also face unique barriers to cycling related to their individual identities (*18*). Therefore, policy makers need to include cyclists' perceptions more explicitly in decision-making processes (*27*).

This research aims to address this gap by understanding people's perceptions of cycling infrastructure provision, their relationships to the physical infrastructure provided, the ways in which sociodemographic characteristics influence those perceptions, and how these are influenced by individual experiences of using cycling infrastructure.

Cycling Equity Analysis in Aotearoa New Zealand

The literature on cycling equity is discussed in detail in a recent paper by Jahanshahi et al. (*16*). Consequently, this section only reports on the cycling equity literature relevant to New Zealand—the location of our case study.

In New Zealand, bicycle usage rates in cities are quite low compared with other cities in developed countries. The lack of popularity of cycling as a mode of transport in New Zealand can be explained, at least in part, by the topography. Evidence suggests that the rates of bicycle usage are even lower among low-income and minority populations, groups who also experience higher rates of obesity compared with the general population (*28*). Māori (the indigenous peoples of Aotearoa New Zealand) have also been found to experience reduced health benefits from cycling as a result of lower bicycle usage rates (*29*). New Zealand Europeans (NZ Europeans) are most likely to be cyclists in New Zealand, whereas Pacific peoples are less likely to use bicycles than other ethnicities (*30*). There is also a considerable gender gap in cycling in New Zealand with three-quarters of regular cyclists being male (*31*).

In New Zealand's Future Streets Program, Thorne et al. focused on one suburb in Auckland (Mangere Central) to explore perceptions of cycling using a mixture of community key informant interviews and focus groups (*32*). Using thematic analysis, the authors identified several factors that influence people's perceptions, including local cycling norms, socioeconomic barriers, appreciation of the new community walking and cycling trail, a desire for connectivity beyond the neighborhood, concerns about on-road bicycle lanes, support for local cycling champions, and tensions between views of the project as "experimentation" rather than "investment."

Jones et al., in a narrative literature review, investigated cycling patterns, barriers, and possible solutions for Māori specifically (*17*). The study showed that the barriers to cycling for Māori are largely similar to those of New Zealand Europeans (NZ Europeans). However, there are some that are particularly relevant to Māori, including inflexible employment conditions, concerns about neighborhood safety, inadequate provision to enable social cycling (i.e., opportunities to cycle with friends and family), and a lack of adequate infrastructure to allow access to places of importance to them. Thus, there is an opportunity to provide solutions for this specific group to make cycling more appealing.

Finally, based on the observed gender inequality in bicycle usage in New Zealand, Russell et al., using a feminist intersectional approach, found that perceptions of traffic danger and personal safety, and the need to be safety conscious because of responsibilities for others, influence women's cycling preferences (*33*). The results also showed that although Māori women are significantly less likely to have access to a bicycle than non-Māori women, Māori women are significantly more likely to be willing to cycle with others compared with non-Māori women, reflecting differences in cultural perspectives with respect to cycling.

Methodology

Study Area: Auckland, Aotearoa New Zealand

Auckland is the most populous city in New Zealand with approximately 1,717,500 residents and covers the largest urban area of 16,155 km^2 (*34*). It is one of the most culturally diverse cities in the world, comprising more than 220 ethnic groups and with four in ten Aucklanders having been born overseas. Auckland and its surrounding areas are home to 60% of the country's indigenous population, Māori, and boasts the largest Polynesian population in the world (*35*). The city has the lowest overall cycling rates among the large cities in New Zealand at 0.4%. In comparison, cycling rates are 3.6% for Christchurch, 1.9% for Tauranga, 1.4% for Wellington, 1.3% for Dunedin, and 1.1% for Hamilton (*30*). The differences in cycling rates can be partly attributed to differences in topography, but also the geographical size of the city.

In this study, participants were recruited from across the Auckland region, spanning 27 different postal codes, as shown in Figure 1, and representing a distribution of age, gender, ethnicity, income, and levels of bicycle infrastructure typical of Auckland. The bicycle lanes that exist in each of these areas are highlighted in Figure 1. Note that these are bike lanes that exist currently, rather than planned bike lanes. As can be seen, some areas in Auckland are devoid of any bicycle infrastructure whereas other areas are well served.

Participants and Questionnaire

The number of participants surveyed per postal code varied based on population size and response rates, and ranged from 9 to 35. Although there were no exclusion criteria, participation was restricted to those aged 18 years and over. Consequently, the elderly and disabled, for whom cycling may not be an option, were not excluded. The questionnaire was only provided in English and was therefore limited to those with a sufficiently high command of the English language to be able to complete it. The questionnaire was administered during the period of May to July 2021. In total, 683 responses were collected. After removing incomplete questionnaires, as well as those that had been answering with patterns, such as providing the same answer to all of the questions and providing very unlikely answers, 506 were retained for data analysis, resulting in a (net) response rate of 74%.

The first section of the questionnaire was related to participant demographics (21 items), including age, ethnicity, gender, education, employment status, income, and access to a car. A summary of the demographic characteristics of the participants is presented in Table 1. The collected data are representative of Auckland with respect to distributions of age, gender, ethnicity, and income levels (*34*), as shown in parenthesis in Table 1.

A summary of the cycling profile of the participants is presented in Table 2, including whether they have access to a bicycle at home, the extent of bicycle usage, the bicycle user type of the participants, and their purpose for cycling if they do indeed cycle. Both cyclists and non-cyclists were included in the data collection. Those categorized as cyclists were split into two groups: regular cyclists and potential cyclists, following the categorization proposed by Wang and Akar (*36*): regular cyclists

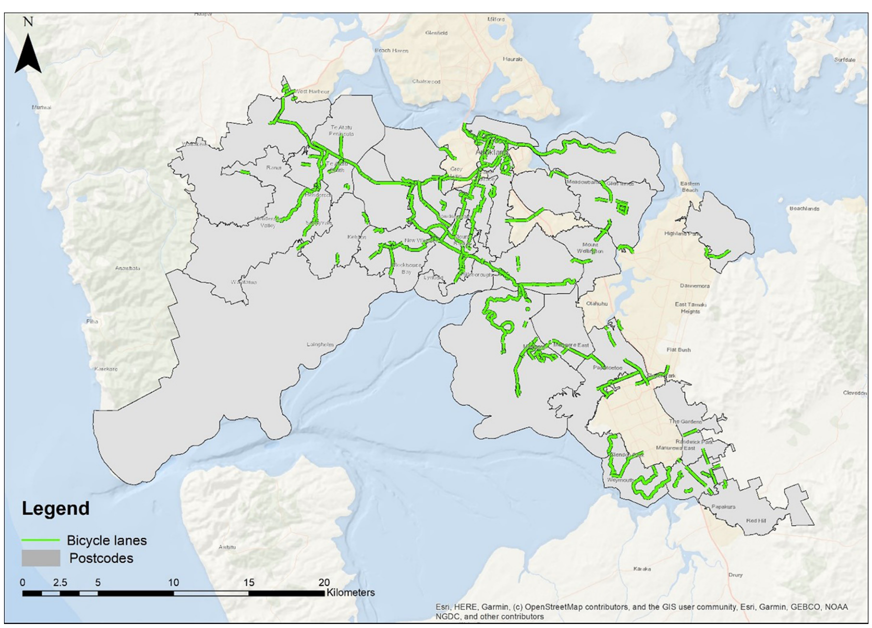

Figure 1. Spatial distribution of bicycle lanes in Auckland.

Table 1. Sociodemographic Characteristics of the Respondents (Completed Responses)

Characteristics	Percentage (Auckland%)
Age (in years)	
18–20	7.5 (not reported)
21–30	19.8 (20.5)
31–40	20.4 (18.8)
41–50	20.4 (17)
51–60	13.5 (15.7)
>60	18.4 (23)
Ethnicity	
Māori	7.1 (11.5)
Pacific Islanders	9.1 (15.5)
Asian	19.8 (28.2)
MELAA	2.2 (2.3)
Indian	10.1 (not reported)
European/NZ European	50 (53.5)
Other ethnicities	1.8 (1.1)
Gender	
Men	44.1 (49)
Women	54.9 (51)
Diverse	1 (not reported)
Highest finished degree	
High school or below	31.7
Undergraduate degree	52.3
Master's degree/Postgraduate	16
Personal annual income (NZD)	
No income	8.7 (8.7)
<30,000	23.9 (36.8)
30,000–70,000	35.6 (34.1)
70,000–100,000	17.7 (10.3)
>100,000	14.1 (9.5)
Employment situation	
Not employed	15.5
Part-time employed	14.7
Full-time employed	52.3
Homemaker	6.2
Retired	11.3
Car access in the household	
Yes	92.1
No	7.3

Note: MELAA: Middle Eastern/African/Latin American; NZD = New Zealand dollars.

are those who indicated having cycled in the past month for any purpose; potential cyclists are those who had cycled at least once in the past 12 months; and noncyclists are those who had not cycled in the past 12 months. Thirty-five participants (6.9%) reported having a disability, but not one that prevented them from cycling. Also, 30% of participants reported that they had experienced injuries because of cycling, one of the factors considered to influence people's perceptions of cycling infrastructure.

The second section of the questionnaire was designed to determine the perceptions of cycling infrastructure. Questions were designed based on a five-point Likert scale (strongly disagree, disagree, neutral, agree, and strongly agree) and asked about the availability of bicycle lanes in the respondents' neighborhood and at their destinations, as well as the quality of road marking and signage. Responses to the three statements below were collected and then used to compute a scale variable for the perceptions of cycling provision:

Table 2. Cycling Profile of the Respondents

Characteristics	Percentage
Access to a bicycle at home	
Yes	46.7
No	53.3
Cycling purpose	
Commuting	9.3
Short trips	25.8
Recreation/exercise	64.9
Average bicycle usage (per week)	
0 times	33
1–3 times	60.4
3–5 times	4.4
>5 times	2.2
Average daily bicycle usage (time)	
<15 mins	32.3
15–30 mins	46.6
30–60 mins	18.4
>60 mins	2.7
Bicycle user type	
Noncyclist	51.6
Regular cyclist	23.7
Potential cyclist	21.1
Cycling injuries	
Yes	30
No	70

- There are sufficient cycling facilities such as bicycle lanes and/or dedicated cycleways in my residential neighborhood;
- There are sufficient cycling facilities to my common destination(s); and
- There are appropriate road marking and bicycle signage in bicycle lanes.

Developing a Bicycle Lane Score for Auckland

The Bike Score index and its components are frequently used to measure the availability of bicycle infrastructure within a neighborhood (*7*, *15*, *37–39*). The Bike Score index is a weighted sum of components, including the Bike Lane Score, Hill Score, Destinations and Connectivity Score, and the recently added Bike Commuting Mode Share Score. To analyze the availability of bicycle lanes, the Bike Lane Score was applied in this analysis, following its use in recent evaluations of bicycle infrastructure availability (*40*).

Table 3. Weights for Bicycle Lanes in Auckland to Calculate Bike Lane Score

Weights	Bike lane category based on Bike Lane Score index	Auckland bicycle lanes
3×	Bike path	On-road protected cycle lanes (two-way)
		Off-road cycle path (only bicycle)
		On-road protected cycle lanes (one-way)
1.5×	Bicycle lane	On-road unbuffered cycle lanes
		On-road buffered cycle lanes
1×	Shared infrastructure	Off-road shared paths (with pedestrians)
		Quiet routes

The Bike Lane Score is a normalized index of a location's proximity to bicycle lanes. Based on the Bike Lane Score (*37*, *40*, *41*), the weighting system takes the sum of the lengths of all nearby bicycle lanes, which is calculated based on a distance decay function to each segment, for which no value is given to segments further than 1,000 m from the origin. Distance decay is the idea that the farther away people are from services, the less likely they are to make use of them. A linear relationship between distance and service accessibility was assumed for distances up to 1,000 m. The weight given for bike paths is 2× that of bicycle lanes, and bike paths are given scores 3× those with shared infrastructure. The weights are assigned to each bicycle lane to compute the Bike Lane Score. The final weighted lengths are then normalized to a score of between 0 and 100, with higher Bike Lane Scores indicating greater availability of bicycle infrastructure and a Bike Lane Score of 0 indicating no infrastructure within 1 km. The Bike Lane Score for each postcode is the density of bicycle lanes calculated as the sum of the scores of bicycle lanes for each area postcode divided by the area (km^2) of each postcode.

In this study, the standard calculation method for the Bike Lane Score was used to analyze the availability of bicycle lanes in Auckland. Auckland has seven types of bicycle lanes, as presented in Table 3. To weight these appropriately, each was grouped into one of three standard categories: bike paths, bicycle lanes, and shared infrastructure. Figure 2 shows the spatial distribution of the Bike Lane Scores for the study area calculated using a geographical information system. On this basis, participants were assigned a score for the availability of bicycle infrastructure (range 0 to 100) based on their residential postal code. The Bike Lane Score for each participant was then categorized as "poor," "average," or "excellent" on the basis of this score, using Jenk's natural breaks classification method (*42*), by selecting the ordered number of classes with a goodness of variance fit (*43*).

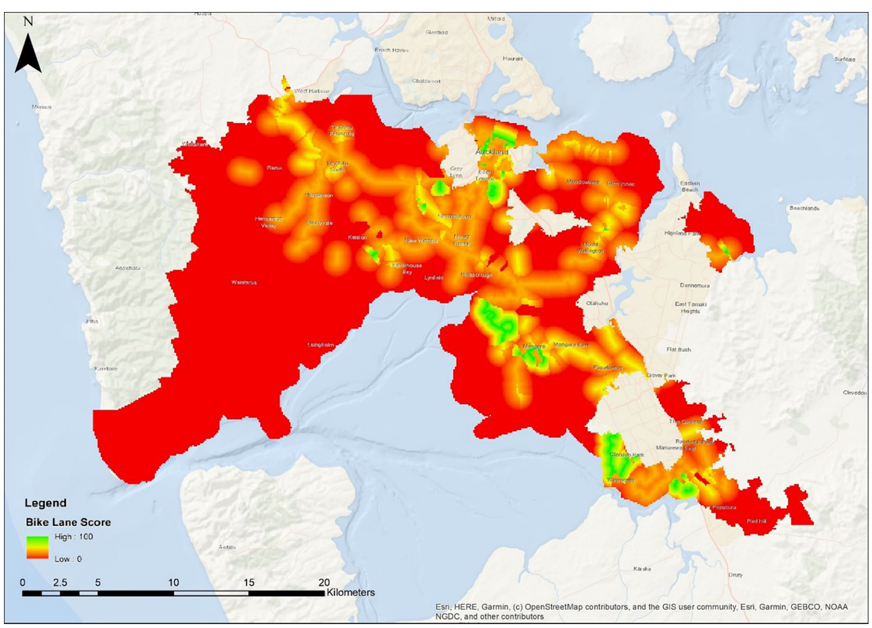

Figure 2. Spatial distribution of bicycle infrastructure, using the Bike Lane Score as a proxy.

Data Analysis Strategy

The first step of the data analysis was to confirm the reliability of the variables used in the study. Carrying out confirmatory factor analysis (CFA) is crucial for determining whether the hypothesized structure of the items and constructs provide an acceptable fit to the data (*44*), and confirming the relationships between a set of observed variables and a set of common items (*45*). Thus, to confirm the convergent and discriminant validity of the questions, CFA was carried out (*46*, *47*), with items with loading factors of less than 0.5 excluded (*48*). The results indicated loading factors of above 0.5 for all of the questions (0.79, 0.78, and 0.54 for Questions 1 to 3 respectively). Cronbach's alpha was also analyzed to confirm the reliability of the questions, with coefficients found to be above 0.7, thus within the acceptable reliability range.

Statistical analyses were conducted using SPSS (Version 25.0). Descriptive statistics were first undertaken with respect to bicycle user type (regular cyclists, noncyclists, and potential cyclists). At this stage, we also assessed and reported the results of chi-square tests for each sociodemographic variable, to evaluate the significance of their relationships with respect to bicycle user type. Then, to identify the factors that influence people's perceptions of cycling infrastructure, a classification and regression tree (CART) analysis was used to classify the participants into groups based on their perceptions of cycling provision. A multiple linear regression was then carried out to analyze the influence of cycling infrastructure availability and sociodemographic characteristics on cycling provision perceptions for each group of bicycle users. Finally, the influence of sociodemographic characteristics and bicycle usage on perceptions of cycling provision was evaluated for each level of infrastructure (poor, average, and excellent) using a series of multiple linear regressions. Note that the influence of cycling infrastructure availability and sociodemographic characteristics on perceptions of cycling provision for cycling purpose groups (commuting and recreation) was investigated. However, because the relationships were not significant or notable, these results are not presented.

Results

Descriptive Analysis of Bicycle User Types

This section presents the sociodemographic characteristics of the participants by bicycle user group, as shown in Table 4, and the results of chi-square tests, to determine whether any of the relationships were significant. The results of the chi-square test showed a significant relationship between age and bicycle user type (χ^2[10, 446] = 63.181, p = 0.000 < 0.005). As evident in Table 4, as the age category of the participants increased, the percentage of noncyclists also increased. The highest percentage of regular cyclists was for the 21 to 30 age category. Interestingly, there was a considerable percentage of potential cyclists among the youngest group of participants (18 to 20 years old). A significant relationship between gender and bicycle user type was found (χ^2[2, 447] = 9.816, p = 0.007 < 0.05). A lower proportion of women are regular cyclists compared with men, however, women do account for more potential cyclists. The chi-square tests showed a significant relationship between ethnicity and bicycle user type (χ^2[10, 447] = 17.753, p = 0.049 < 0.05). The lowest percentage of regular cyclists was for European and Pacific Islanders, and a considerable percentage of Pacific Islanders were noncyclists (64.9%). Interestingly, compared with other ethnicities, a high proportion of Māori are potential cyclists, suggesting that opportunities exist to encourage this group to become regular cyclists. A nonsignificant relationship between access to a car and bicycle user type was revealed (χ^2[2, 444] = 2.475, p = 0.29 > 0.05). The results of the chi-square test showed a significant relationship between access to a bicycle and bicycle user type (χ^2[2, 446] = 190.661, p = 0.000 < 0.005). Access to a bicycle was high among regular cyclists (necessarily), however, 19.2% of those with access to a bicycle were noncyclists and 31.9% of them were potential cyclists. A nonsignificant relationship between cycling injuries and bicycle user type was found (χ^2[2, 443] = 4.241, p = 0.120 > 0.05). The results of the chi-square test also showed a nonsignificant relationship between income level and bicycle user type (χ^2[8, 444] = 8.744, p = 0.364 > 0.05). The results revealed a significant relationship between employment situation and bicycle user type (χ^2[8, 445] = 36.624, p = 0.000 < 0.005). Retired people had the highest percentage of noncyclists (79.2%) and the lowest percentage of regular cyclists and potential cyclists. The results of the chi-square test show a significant relationship between education level and bicycle user type (χ^2[4, 431] = 16.746, p = 0.002 < 0.005). As the level of education of the participants increased, the percentage of regular cyclists also increased. The results of the chi-square test showed a significant relationship between cycling as the main purpose for using a bike and bicycle user type (χ^2[4, 215] = 11.975, p = 0.003 < 0.005). Those who used a bicycle for recreational purposes were more likely to be potential cyclists, whereas those who used a bicycle for commuting and short trips were more likely to be regular cyclists.

Classification and Regression Tree (CART) Analysis

This section presents the results of the CART analysis to identify the ways in which different population groups

Table 4. Demographic Characteristics of Bicycle User Types

Sociodemographic characteristics	Categories	Regular cyclists (%)	Potential cyclists (%)	Noncyclists (%)
Age	18–20	20.6	41.2	38.2
	21–30	42.4	18.5	39.1
	31–40	37	23.9	39.1
	41–50	25.8	23.7	50.5
	51–60	9.4	32.8	57.8
	>60	10.1	11.2	78.7
Gender	Male	32.5	20.8	46.7
	Female	19.6	24.7	55.7
Ethnicity	Māori	24.2	36.4	39.4
	Pacific Islander	16.2	18.9	64.9
	Asian/Indian	30.7	21.2	48.2
	European	16	30	54
	NZ European	25.3	19.6	55.2
	MELAA	38.9	33.3	27.8
Access to a car	Yes	26.3	22.1	51.6
	No	19.4	30.6	50
Access to a bicycle	Yes	48.9	31.9	19.2
	No	3.3	14.2	82.4
Cycling injury experience	Yes	30.2	25.2	44.6
	No	23.7	21.8	54.5
Income level (thousands)	No income	12.5	27.5	60
	<30	24.5	27.3	48.2
	30–70	24.4	22.6	53
	70–100	30.1	15.7	54.2
	>100	32.3	23.1	44.6
Employment situation	Not employed	17.6	32.4	50
	Part-time	28.1	34.4	37.5
	Full-time	32	20	48
	Homemaker	16	12	72
	Retired	9.4	11.3	79.2
Education level	High school and below	13.4	26.1	60.6
	Bachelors and diploma	29.7	23.3	47
	Postgraduate	35.3	17.6	47.1
Cycling purpose	Commuting	76.2	23.8	na
	Short trips	67.2	32.8	na
	Recreation/exercise	44.5	55.5	na

Note: MELAA: Middle Eastern/African/Latin American; na = not applicable.

differed in relation to their perceptions of cycling provision. CART is a type of decision tree classification algorithm that uses binary recursive partitioning (*49*). CART analysis selects the best predictor variable for splitting the data into clusters with maximal purity. The process is repeated recursively for each cluster, until either the minimum size of the terminal cluster is reached, or no further split improves the purity of the terminal cluster (*50*, *51*), in this case, until the clusters were significantly different to each other in relation to cycling infrastructure perceptions.

As shown in Figure 3, the strongest factor influencing perceptions of bicycle infrastructure provision was bicycle user type. People who were regular cyclists fell into a different cluster to the noncyclists and potential cyclists. Regular cyclists had a higher level of perception (valued them more) about cycling provision compared with noncyclists and potential cyclists. Among the noncyclists and potential cyclists, ethnicity was the strongest demographic factor, resulting in three clusters: 1) Māori and Pacific Islanders (highest level of perception:highest value for perception); 2) NZ European and Asian/Indian; and 3) European and Middle Eastern/African/Latin American (MELAA) (lowest level of perception:lowest value for perception). The responses provided by the NZ European and Asian/Indian participants were then classified into two clusters based on their level of education: 1) lower level of education with a higher level of perception with respect to cycling provision (valued them more), and 2) higher level of education with a lower level of perception (valued them less) of cycling provision. Surprisingly, the availability of bicycle lanes was not found to influence respondents' perceptions within this classification, with bicycle user type,

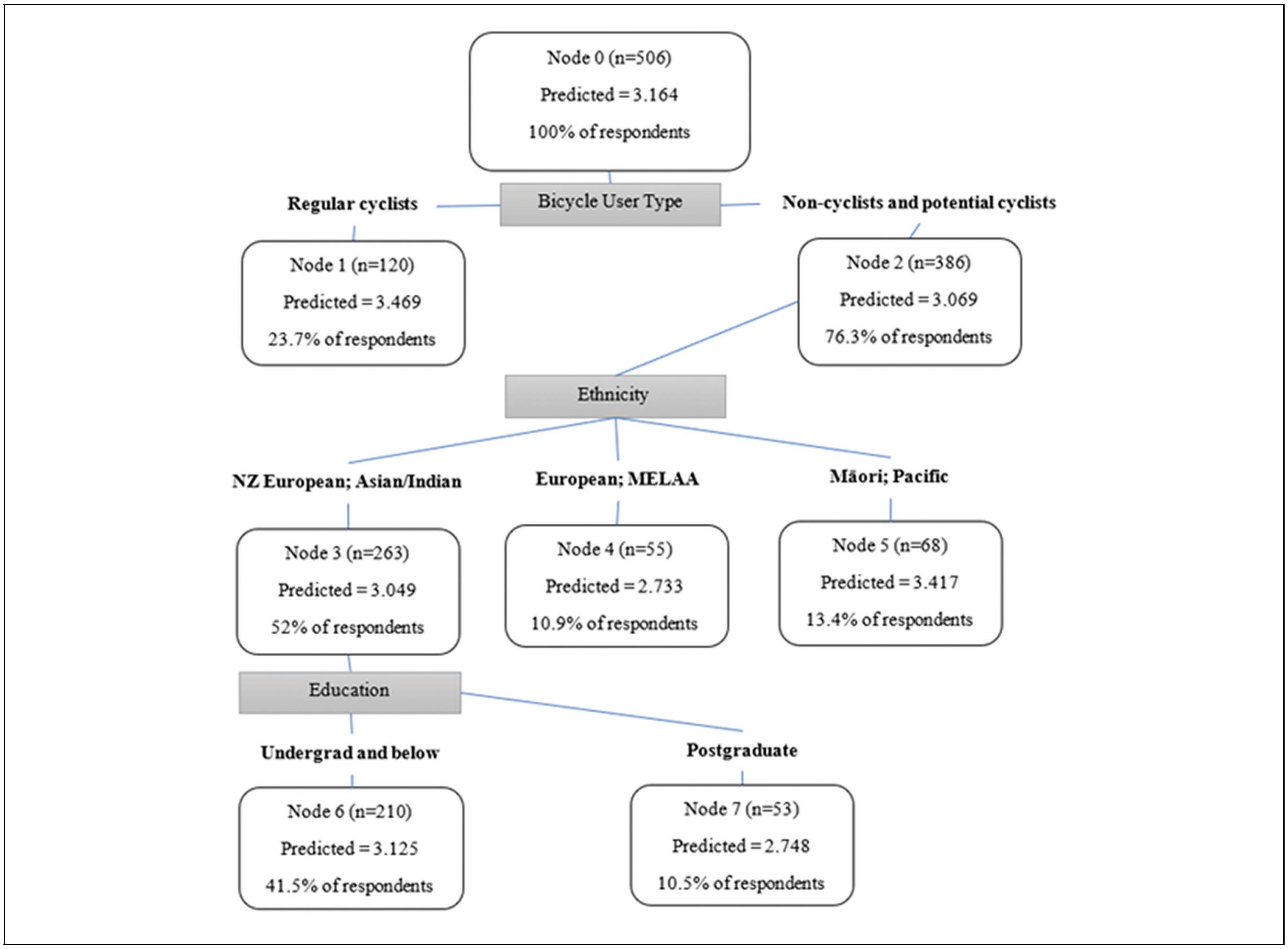

Figure 3. Results of classification and regression tree analysis for cycling provision perceptions.
Note: The "predicted" values express the mean score based on the five-point Likert scale.

ethnicity, and education level being the most important factors influencing perceptions. The subsequent sections present further analyses carried out to highlight the factors influencing the perceptions of each bicycle user group about cycling provision.

Factors Influencing Perceptions of Cycling Provision by Bicycle User Type

Table 5 presents the results of a multiple linear regression analysis for regular cyclists, investigating the impact of age, gender, ethnicity, education level, annual income, Bike Lane Score, cycling injury, access to a car, access to a bicycle, and employment status on perceptions of cycling provision. The results showed that for this group, age, education level, cycling injury, and Bike Lane Score all influenced cycling provision perceptions, resulting in a significant regression equation for the model (χ^2[32, 109] = 47.671, $p = 0.037 < 0.05$). Scaled deviance and Akaike's information criterion (AIC) were 109 and 258.562, respectively. Pairwise comparisons were then used to understand the relationship between the independent variables, including age, gender, education, cycling injury, Bike Lane Score, and cycling provision perceptions (Appendix 1). The results showed that in this group, overall, younger people had higher perceptions of bicycle infrastructure (valued them more). Among regular cyclists, people who had postgraduate qualifications were found to have higher perceptions (valued them more) compared with those with bachelor and diploma-level qualifications. In addition, having experienced a cycling injury was shown to significantly adversely affect a cyclist's perceptions of bicycle infrastructure. Lastly, people who lived in areas with excellent levels of bicycle infrastructure had higher perceptions of cycling infrastructure than people who lived in areas with poor or average levels of bicycle infrastructure.

Table 6 presents similar results to Table 5 but this time for noncyclists and potential cyclists. We combined noncyclists and potential cyclists into one group based

Table 5. Multiple Linear Regression for Predicting Cycling Provision Perception by Regular Cyclists (Sample Size = 109)

Independent variable	Regression coefficients	Standard error	Chi-square	df	*p*-Value
Intercept	4.084	0.6506	107.113	1	0.000
Ethnicity	NA	NA	8.891	5	0.113
Age	NA	NA	24.283	5	0.001
18–20	−1.413	0.3773	14.038	1	0.000
21–30	−0.192	0.2478	0.603	1	0.438
31–40	−0.592	0.2818	4.410	1	0.036
41–50	−0.120	0.2629	0.210	1	0.647
51–60	−1.067	0.3289	10.531	1	0.001
>60	0	NA	NA	NA	NA
Gender	NA	NA	10.585	2	0.646
Education level	NA	NA	8.422	2	0.020
High school and below	−0.226	0.2886	0.614	1	0.433
Bachelor and diploma	−0.486	0.2376	4.193	1	0.041
Postgraduate	0	NA	NA	NA	NA
Annual income (NZD)	NA	NA	1.478	4	0.830
Cycling injury	NA	NA	4.806	1	0.028
Yes	−0.275	0.1487	3.415	1	0.028
No	0	NA	NA	NA	NA
Access to a car	NA	NA	1.555	1	0.212
Employment	NA	NA	1.456	4	0.834
Access to a bicycle	NA	NA	0.863	1	0.353
Main cycling purpose	NA	NA	0.610	2	0.737
Cycling time per week	NA	NA	0.108	3	0.991
Cycling time per journey	NA	NA	0.029	2	0.985
Bike Lane Score	NA	NA	14.515	2	0.001
Scale	0.336	0.0456	NA	NA	NA

Note: NZD = New Zealand dollars; NA = not available..
Shading indicates significant associations ($p < 0.05$)

Table 6. Multiple Linear Regression for Predicting Cycling Provision Perception by Noncyclists/Potential Cyclists (Sample Size = 309)

Independent variable	Regression coefficients	Standard error	Chi-square	df	*p*-Value
Intercept	2.862	0.3292	75.564	1	0.000
Ethnicity	NA	NA	22.336	5	0.000
Asian/Indian	−0.215	0.1584	1.847	1	0.174
European	−0.603	0.1812	11.060	1	0.001
Māori	0.181	0.2261	0.643	1	0.423
MELAA	−0.977	0.3417	8.177	1	0.004
NZ European	−0.275	0.1632	2.832	1	0.092
Pacific	0	NA	NA	NA	NA
Age	NA	NA	6.304	5	0.278
Gender	NA	NA	1.254	2	0.534
Education level	NA	NA	5.388	2	0.068
Annual income (NZD)	NA	NA	6.657	4	0.155
Cycling injury	NA	NA	0.139	1	0.709
Access to a car	NA	NA	0.266	1	0.606
Employment	NA	NA	2.749	4	0.601
Access to a bicycle	NA	NA	1.071	1	0.301
Bike Lane Score	NA	NA	3.562	2	0.168

Note: NZD = New Zealand dollars; NA = not available.
Shading indicates significant associations ($p < 0.05$).

Table 7. Multiple Linear Regression for Predicting Cycling Provision Perceptions in Areas with Poor Levels of Infrastructure (Sample Size = 233)

Independent variable	Regression coefficients	Standard error	Chi-square	df	p-Value
Intercept	3.245	0.4157	60.932	1	0.000
Age	NA	NA	4.182	5	0.524
Gender	NA	NA	1.753	2	0.416
Ethnicity	NA	NA	18.668	5	0.003
Asian/Indian	−0.096	0.2373	0.163	1	0.686
European	−0.652	0.2785	5.483	1	0.019
Māori	0.250	0.2829	0.781	1	0.377
MELAA	−0.820	0.3125	6.878	1	0.009
NZ European	−0.233	0.2291	1.033	1	0.310
Pacific	0	NA	NA	NA	NA
Education level	NA	NA	2.912	2	0.233
Employment	NA	NA	2.886	4	0.577
Annual income (NZD)	NA	NA	1.159	4	0.885
Access to a bicycle	NA	NA	5.318	1	0.017
Yes	0.351	0.1463	5.742	1	0.017
No	0	NA	NA	NA	NA
Bicycle user type	NA	NA	2.307	2	0.315
Cycling injury	NA	NA	1.344	1	0.246
Access to a car	NA	NA	0.126	1	0.723

Note: NZD = New Zealand dollars; NA = not available.
Shading indicates significant associations ($p < 0.05$).

on the results of the CART analysis, which showed no significant difference for cycling provision perceptions for these groups. The results of the model revealed a significant regression equation (χ^2[25, 309] = 49.313, $p = 0.003 < 0.005$). Scaled deviance and AIC were 309 and 767.152, respectively. In this case, ethnicity was the main factor influencing cycling provision perceptions. Pairwise comparisons were then used to understand the relationship between ethnicity and cycling provision perceptions among noncyclists/potential cyclists (Appendix 2). The results showed that Māori, Pacific Islanders, and NZ European had significantly higher perceptions of bicycle infrastructure compared with MELAA and Europeans.

Factors Influencing Cycling Provision Perceptions in Areas With Poor, Average, and Excellent Bicycle Infrastructure

This section investigates the factors influencing the perceptions of respondents with respect to cycling infrastructure when normalized for the availability of bicycle infrastructure. Specifically, this section assesses the impact of age, gender, ethnicity, education level, annual income, bicycle user groups, cycling injury, access to a car, access to a bicycle, and employment status on the respondents' perceptions of cycling provision for each level of bicycle infrastructure, clustered into the three levels: poor, average, and excellent.

Among those who lived in areas with poor levels of bicycle infrastructure (282 participants), 23.1% were regular cyclists, 92.9% had access to a car, and 93.6% knew how to ride a bike. A multiple linear regression was undertaken to predict cycling provision perceptions, with a significant regression equation found for the model (χ^2[26, 233] = 39.233, $p = 0.046 < 0.05$). Scaled deviance and AIC were 233 and 601.327, respectively. The results showed that ethnicity and access to a bicycle influenced cycling provision perceptions within this group (Table 7). Pairwise comparisons were also used to understand the relationship between ethnicity and access to a bicycle and cycling provision perceptions (Appendix 3). The results showed that Māori, Pacific Islanders, and NZ Europeans had significantly higher perceptions of bicycle infrastructure (valued them more) compared with others when they lived in areas with a poor level of bicycle infrastructure. By contrast, MELAA and Europeans expressed lower perceptions (valued them less) about cycling provision compared with others. Finally, those who had access to a bicycle had higher levels of perception about cycling provision (valued them more).

Among those who lived in areas with an average level of bicycle infrastructure (130 participants), 27.1% were regular cyclists and 96.1% had access to a car. As before, the association between sociodemographic characteristics and cycling provision perceptions was assessed among this group. A multiple linear regression was undertaken to predict cycling provision perceptions revealing a nonsignificant regression equation for the model (χ^2[26,

Table 8. Multiple Linear Regression for Predicting Cycling Provision Perception in Areas with Average Levels of Infrastructure (Sample Size = 107)

Independent variable	Regression coefficients	Standard error	Chi-square	df	*p*-Value
Intercept	2.970	0.5516	28.997	1	0.000
Age	NA	NA	3.998	5	0.550
Gender	NA	NA	2.321	2	0.313
Ethnicity	NA	NA	7.859	5	0.164
Education level	NA	NA	3.389	2	0.184
Employment	NA	NA	5.818	4	0.213
Annual income (NZD)	NA	NA	10.081	4	0.049
Access to a bicycle	NA	NA	2.859	1	0.091
Bicycle user type	NA	NA	8.342	2	0.019
Cycling injury	NA	NA	3.241	1	0.072
Access to a car	NA	NA	0.567	1	0.451

Note: NZD = New Zealand dollars; NA=not available.

Table 9. Multiple Linear Regression for Predicting Cycling Provision Perception in Areas with Excellent Levels of Infrastructure (Sample Size = 78)

Independent variable	Regression coefficients	Standard error	Chi-square	df	*p*-Value
Intercept	3.796	0.6121	38.454	1	0.000
Age	NA	NA	10.138	5	0.071
Gender	NA	NA	1.473	2	0.479
Ethnicity	NA	NA	11.135	5	0.049
Asian/Indian	−0.883	0.3535	6.239	1	0.012
European	−0.619	0.4050	2.334	1	0.027
Māori	−0.086	0.4563	0.036	1	0.850
MELAA	−0.631	0.5343	1.395	1	0.018
NZ European	−0.646	0.3475	3.460	1	0.113
Pacific	0	NA	NA	NA	NA
Education level	NA	NA	4.606	2	0.100
Employment	NA	NA	6.234	4	0.182
Annual income (NZD)	NA	NA	22.368	4	0.001
No income	0.250	0.5168	0.234	1	0.629
<30,000	−0.954	0.3792	6.333	1	0.012
30,000–70,000	−0.227	0.2643	0.735	1	0.391
70,000–100,000	−0.229	0.2846	0.649	1	0.421
>100,000	0	NA	NA	NA	NA
Access to a bicycle	NA	NA	1.507	1	0.220
Bicycle user type	NA	NA	35.514	2	0.000
Regular cyclist	0.696	0.2388	8.504	1	0.004
Potential cyclist	−0.642	0.2444	6.888	1	0.009
Noncyclist	0	NA	NA	NA	NA
Cycling injury	NA	NA	0.063	1	0.801
Access to a car	NA	NA	3.302	1	0.069

Note: NZD = New Zealand dollars; NA=not available.
Shading indicates significant associations ($p < 0.05$).

107] = 32.131, $p = 0.189 > 0.05$). The results showed that there was no significant association between the independent variables and cycling provision perceptions (Table 8).

Among those who lived in areas with an excellent level of bicycle infrastructure (94 participants), 28.7% were regular cyclists and 86.2% had access to a car. In this case the multiple linear regression revealed a significant regression equation for the model (χ^2[26, 78] = 58.520, $p = 0.000 < 0.005$). Scaled deviance and AIC were 78 and 191.1, respectively. According to Table 9, ethnicity, annual income, and bicycle user type all influenced cycling provision perceptions, and pairwise comparisons were used to understand the relationship between the independent variables and cycling provision perceptions (Appendix 4). The results showed that, once again, Māori and Pacific Islanders were the groups with the highest levels of perception, whereas European and Asian/Indian participants had lower levels of perception. Differences among income-level groups did not reveal any meaningful patterns. The results also showed that regular cyclists had significantly higher levels of perception compared with noncyclists and potential cyclists. Surprisingly, noncyclists had significantly higher levels of perception compared with potential cyclists.

Discussion and Conclusions

This research aimed to understand people's perceptions of cycling infrastructure provision, its relationship to the physical infrastructure provided, and how sociodemographic characteristics influence those perceptions. We investigated the factors influencing different cycling provision perceptions among various groups and the extent to which objective factors (in this case the availability of bicycle lanes) played a role in individual perceptions of cycling infrastructure. Auckland, New Zealand was chosen as the city of interest owing to its low bicycle usage rates and high level of ethnic diversity within its population. The study considered the demographics of bicycle users/nonusers across a wide range of bicycle infrastructure availability to provide a holistic understanding of the factors associated with people's perceptions about cycling infrastructure provision.

In this study, the impact of sociodemographic characteristics and the availability of bicycle lanes on cycling provision perceptions were examined. A CART analysis confirmed that population groups in Auckland clustered into seven groups influenced by bicycle user type, ethnicity, and level of education. Interestingly, the availability of bicycle lanes was not found to be a factor influencing the clustering of population groups. The first cluster separated regular cyclists from noncyclists/potential cyclists. Regular cyclists had higher levels of perception of bicycle infrastructure compared with noncyclists/potential cyclists. All other clusters were subsets of noncyclists/potential cyclists. Based on the significantly larger number of noncyclists and potential cyclists in Auckland (consistent with the low bicycle usage rates), more attention needs to be given to this group to better understand the factors that could encourage and empower them to use a bicycle. The noncyclists/potential cyclists were further clustered into three ethnic groups. NZ Europeans and Asians/Indians were clustered in two groups based on education level. Although the impact of bicycle user type, ethnicity, and education on differentiating people's perceptions about cycling infrastructure was clear in the case of Auckland city, the CART analysis indicated that the provision of cycling infrastructure did not have a major influence on people's perceptions. Therefore, we argue that it is important for local policy makers to implement a variety of cycling initiatives, and not focus only on cycling infrastructure provision.

Descriptive analyses indicated that Māori had the highest percentage of potential cyclists among all ethnicities. This is consistent with the line of argument by Jones et al. who suggest that there is significant potential to achieving a high level of uptake of cycling among Māori (*17*). Pacific Islanders had the highest percentage of noncyclists (64.9%), the lowest percentage of potential cyclists, and one of the lowest percentages of regular cyclists. This finding is also consistent with previous studies reported in the literature (e.g., Shaw and Russell [*30*]). Younger people were the most likely to be regular cyclists or potential cyclists, whereas most elderly were noncyclists. The high level of potential among people 18 to 20 years old indicated that more attention to this group's needs could considerably increase bicycle uptake in Auckland. Women made up a lower percentage of regular cyclists compared with men, whereas a higher percentage of potential cyclists were women. This suggests that there are opportunities to encourage women in Auckland to cycle more. Bicycle usage among those with no access to a bicycle at home was extremely low (3.3% were regular cyclists), suggesting that a better distribution of BSS and DBSS could be helpful for providing access to bicycles for those without a bicycle. The higher percentage of bicycle usage found among those with a higher level of education might indicate that raising awareness of the option to cycle and educating about the benefits of cycling among noncyclists could be helpful. In addition, the lower percentage of bicycle usage found among people with lower incomes might indicate that more analyses on affordability of cycling in Auckland could help address this issue.

The results of the regression analyses showed that whereas for regular cyclists, age, education level, and cycling injury experience affected perceptions of cycling provision, for noncyclists, only the ethnicity of noncyclists and potential cyclists significantly influenced perceptions of cycling provision. It could therefore be argued that for people who are not currently or regularly cycling, only sociocultural background plays a significant role in perceptions. As for the influence of education level, this may be linked to employment conditions and, therefore, inflexibilities in the workplace being a barrier to using a bicycle (*17*). It is important to note that the influence of sociodemographic characteristics is not shaped by a single axis of social division and it is the "intersections of them" (the combination of multiple sociodemographic variables) that create differences among different population groups (*52*). Among the regular cyclists, younger, male, those more educated, and those living in areas with an excellent level of bicycle infrastructure had higher perceptions of cycling infrastructure. People who had experienced cycling injuries had lower perceptions of cycling infrastructure. The ethnicity of regular cyclists was not found to be a factor influencing the different perceptions of cycling provision. However, for both noncyclists and potential cyclists, ethnicity played an important role. European and MELAA participants had significantly lower levels of perception about bicycle infrastructure. This could be a result of the less developed infrastructure in Aotearoa New Zealand compared with certain European countries, or could be related to the unrealized expectations that some people from less developed countries have about Aotearoa New Zealand's cycling infrastructure. Thus, understanding the differences between different communities' expectations about bicycle infrastructure related to sociocultural background could play an important role in policy making. Interestingly, although Māori and Pacific people had the highest level of perceptions (valued them most) about cycling provision, studies have shown that bicycle usage rates among Māori and Pacific people remain significantly lower than for other ethnicities (*30*).

Cycling provision perceptions were also investigated when normalized for the availability of bicycle infrastructure. The results illustrated that ethnicity and access to a bicycle were factors that shaped the perceptions of people who lived in areas with a poor level of bicycle infrastructure. Annual income, bicycle user type, and ethnicity were the factors found to influence people's perceptions in areas with an excellent level of bicycle infrastructure. Ethnicity played a significant role in relation to cycling provision perceptions in areas with poor and excellent levels of bicycle infrastructure. For the areas with an average level of bicycle infrastructure, there was no significant relationship between the independent variables and cycling provision perceptions.

People's perceptions could influence planning for the provision of bicycle infrastructure and, therefore, could play a role in equity analysis. The current study has shown that cycling provision perceptions were more affected by factors such as ethnicity, education, and bicycle user type than objective measures of bicycle infrastructure provision. It has also shown that people with different backgrounds had different perceptions about the same level of infrastructure. Following the capabilities approach of justice (*20*, *21*), focusing only on the provision of cycling resources such as bicycle lanes could be misleading, and sociocultural factors such as ethnicity should also be considered to fairly encourage and empower all population groups to use bicycles. The results of this study suggested that equity in cycling should be a holistic system that considers equity in the provision of cycling initiatives such as education and awareness as well as equity in the provision of cycling infrastructure. People need other motivations, in addition to bicycle infrastructure, and it is important to ensure equity is achieved in all aspects of cycling provision such as encouragement, awareness, skills, and, more importantly, community-focused initiatives. Initiatives that address particular barriers for specific groups could help improve equity in cycling. For example, Jones et al. and Russell et al. highlighted concerns about neighborhood safety, addressing inadequate provision to enable social cycling, and addressing a lack of adequate infrastructure to allow access to places of importance to Māori (*17*, *33*).

Consideration of individual perceptions could be critical in the development of cycling demand and supply indices and, ultimately, more equitable investment prioritization—a step toward cycling equity analysis planning "with" people, as well as "for" people. Traditionally, equity in cycling has focused on the provision of cycling infrastructure to meet equity needs. However, as Levinson argued, a policy deemed equitable to researchers or policy makers may not necessarily be considered equitable by those affected by the policy. An equitable cycling policy should, therefore, also consider population needs and perceptions (*53*).

Limitations

One potential limitation of any study of this type is the risk of bias resulting from self-selection and respondents tending to provide socially desirable answers. Self-selection is unavoidable in that the participants are those who received the online questionnaire and decided to complete it. In addition, the standard weights for the Bike Lane Score were used in this study for reasons of consistency with other studies in the international literature; however, it is acknowledged that the generalizability of the original study may be a limitation. Finally, the results of the present study cannot be easily generalized, but it is anticipated that the results could be applicable to other medium-sized, multicultural cities in similar contexts (geographical, economic, and sociocultural).

Recommendations for Future Research

Future studies should focus on understanding how cycling equity policies could be implemented to bring about a higher level of bicycle usage for different communities, ethnicities, and people with different backgrounds, by considering not only the provision of infrastructure but other influencing factors. Further studies focusing specifically on the expectations of indigenous (especially Māori in Aotearoa New Zealand) and other ethnicities with respect to the provision of cycling infrastructure could provide a pathway to better-informed cycling equity policies. Further research is required to understand the extent to which the low level of bicycle usage among Māori and Pacific people is linked to sociocultural factors, despite their higher perceptions (more value) of bicycle infrastructure provision. Future studies could also explore how to prioritize, under the realities of constrained budgets, the provision of different cycling resources to address differing needs, attitudes, and preferences. In addition, longitudinal studies are needed to better understand the impact of cycling equity policies over time.

Author Contributions

The authors confirm contribution to the paper as follows: study conception and design: D. Jahanshahi, S. Chowdhury, S. B. Costello; data collection: D. Jahanshahi; analysis and interpretation of results: D. Jahanshahi, S. B. Costello, K. Natasha Dirks, B. van Wee; draft manuscript preparation: D. Jahanshahi, S. B. Costello, K. Natasha Dirks, B. van Wee. All authors reviewed the results and approved the final version of the manuscript.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

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Supplemental Material

Supplemental material for this article is available online.

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