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Who benefits from cycling initiatives? An evaluation of perceived effectiveness and differences among population groups

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ABSTRACT

This study explores the effectiveness of cycling initiatives in encouraging bicycle usage, and the relationship with sociodemographic characteristics amongst residents of the multi-cultural city of Auckland, New Zealand. The study considered regular cyclists, potential cyclists, as well as non-cyclists across demographic groups, including age, gender, income level, educational level, ethnicity, and bicycle user type to provide a holistic understanding of the association between the perceived effectiveness of cycling initiatives in encouraging bicycle usage. The results indicate that safety initiatives, including lighting improvements and vehicle safety features are perceived as being the most effective amongst all of the cycling initiatives proposed, and that younger people, Māori and Pacific people, and regular cyclists perceive higher levels of effectiveness in response to many of the cycling initiatives implemented. Moreover, findings indicate that many of the cycling initiatives are seen as more effective by some specific demographic groups who were not necessarily the intended target groups for the initiative, as envisaged by the experts tasked with their development and implementation. Also, for some demographic groups such as the elderly, women and non-cyclists, the perceived effectiveness of current cycling initiatives was found to be lower than was the case for the population as a whole, suggesting that the current cycling initiatives are not sufficiently focussed on these cycling disadvantaged groups, as they should to be in the interest of equity. This study aids in the design of better strategies by providing insights for policymakers and local governments to provide more equitable outcomes with respect to cycling.

1. Introduction

Urban transportation systems should be designed to counteract the negative aspects of rapid urbanization and increased demand for transportation, while ensuring access for all. This can be addressed by providing alternative transportation modes for better access, economically and socially (Mateo-babiano, 2015). Achieving sustainable transportation is, therefore, a key challenge presented by rapid urbanization and its associated health, social, economic, and environmental issues (Ahmad and Puppim de Oliveira, 2016). Bicycles can be considered as one of the most efficient methods of achieving sustainable urban mobility (Berloco and Colonna, 2012), given their minimal consumption of energy and resource (Shaheen et al., 2011). Bicycles are ideal vehicles for short distances, and can also be integrated with other transportation modes to cover medium and long distances. The use of bicycles includes a range of health, environmental and socioeconomic benefits. Using bicycles instead of motor vehicles improves air quality and health outcomes, as well as decreasing traffic congestion, fuel consumption, and the cost of transportation (Shaheen et al., 2010; Berloco and Colonna, 2012; Bernatchez et al., 2015; Karki and Tao, 2016; Midgley, 2011; Tran et al., 2015). It is, therefore, no surprising that many countries promote bicycle usage as a vital strategy to reduce reliance on motor vehicles.

In New Zealand, studies have suggested that cycling benefits are not evenly distributed across the population. Specifically, while Māori (the indigenous population in New Zealand) receive significantly fewer health benefits from cycling generally (Bassett et al., 2020), the relative benefits are higher when they do partake in cycling (Jones et al., 2020). As reported by the Ministry of Health (2022), rates of obesity are higher among minority populations and those on lower incomes, while their bicycle usage rates are lower. Amongst the various ethnic groups, the least likely to be cyclists are Pacific peoples, while European New Zealanders are the most likely to be cyclists (Shaw and Russell, 2017). In

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addition, evidence shows a significant disparity in terms of the gender gap, with only one-quarter of regular cyclists in New Zealand being female (Shaw et al., 2020). Given the inequalities in bicycle usage that exist, and the unequal levels of general health amongst population groups, there is benefit in investigating cycling equity in New Zealand.

Studies on cycling equity have typically focussed on the association between the provision of cycling infrastructure and socio-economic characteristics of population groups, such as income levels as well as place of residence and employment (Pistoll and Goodman, 2014; Fuller and Winters, 2017; Houde et al., 2018; Mooney et al., 2019; Kent and Karner, 2019; Qian and Niemeier, 2019). A significant body of research has analysed the access to cycling infrastructure, such as bicycle lanes, access to bike-sharing systems (BSS) and dock-less bike-sharing systems (DBSS), or access to key destinations by bicycle (Tucker and Manaugh, 2018; Chen et al., 2019; Hosford and Winters, 2018; Winters et al., 2018). These studies have found that minority population groups, people who live in lower-income areas, the elderly, women and immigrants, cycle less than others and, usually, have relatively poor access to cycling infrastructure or bicycle sharing systems (Jahanshahi et al., 2021).

In cycling equity studies, there is a lack of literature on cycling initiatives other than access to bicycle lanes and bicycle sharing systems. Therefore, it is important to first identify the range of cycling initiatives that have been implemented, and then to assess their effectiveness for different socio-demographic groups. A previous study, undertaken by Jahanshahi et al. (2023), identified the range of cycling initiatives provided in Auckland, the most populous city in New Zealand, though semi-structured interviews with experts (policymakers, decision-makers, planners, designers, and transportation professionals). The study also explored their perceptions in terms of the intended target groups and resulting beneficiaries of the cycling initiatives. However, the perceptions of these initiatives from the point of view of the different population groups for whom they were intended have yet to be considered. This is important because people encounter unique barriers to cycling depending on their sociodemographic characteristics and individual identity (Vietinghoff, 2021). There is, therefore, a need for closer attention to be paid to the unique circumstances of different communities and demographic groups within the population. As argued by Cropanzano et al. (2015), the level of satisfaction and the decision outcome success could be influenced by people's attitudes and their perceptions of how they have been affected by a decision. Therefore, it would be helpful to understand to what extent the perceptions of experts differ from those of the people that they serve in terms of the effectiveness of cycling initiatives to encourage cycling, as well as evaluating differences among different population groups. Consequently, this study attempts to answer the questions below:

How do different population groups rate the effectiveness of cycling initiatives to encourage cycling?
Which cycling initiatives are most effective to stimulate population groups with low bicycle usage rates to cycle more?

The findings of this study will provide a better understanding about the perceived effectiveness of different cycling initiatives and will help ensure that decision makers are better equipped to develop policies for improving cycling equity in Auckland.

2. Methodology

2.1. Participants and questionnaire

Participants from across the Auckland Region were recruited via email using a survey distribution company tasked with ensuring a representative distribution of income, gender, age, and ethnicity amongst study participants. Auckland, the largest city in New Zealand, has a population of approximately 1,695,200 and a land area of 4941.16 km^2 (www.stats.govt.nz, 2022). Auckland population is also cultural diverse, encompassing a wide range of ethnic, cultural and racial backgrounds. However, when compared to other major cities in New Zealand, it has the lowest bicycle usage rates, with an estimated 1% and 1.5% cycling for travel to work and education, respectively (www.stats.govt.nz, 2022). Participation was limited to those 18 years of age and older, consequently it is possible that for some participants cycling may not be an option, due to their age or a disability. A possible limitation of this study might be the selection effect due to the language barrier, given that the questionnaire was written in English. The questionnaire was circulated during October and November 2022. From a total of 1163 responses, 732 were retained for data analysis after removing questionnaires containing invalid answers and questionnaires that were incomplete.

The first section of the questionnaire collected sociodemographic characteristics of the respondents. This included age, gender, ethnicity, education, income, employment status, and whether they have access to a car. Table 1 includes a summary of the responses from the study participants. The Auckland population distributions for income, gender, age, and ethnicity (www.stats.govt.nz, 2022) are also included in parenthesis in Table 1, indicating that the sample is representative of the Auckland population.

Table 2 includes a summary of the participants' cycling profiles. This includes information about their access to a bicycle at home, how often they cycle, their use of BSS, and their reasons for cycling. Cyclists and non-cyclists are both considered in the study. However, similar to Félix et al. (2017), those identified as 'cyclists' were further categorised into two groups: 'Potential Cyclists' and 'Regular Cyclists'. Regular Cyclists include respondents who rode a bicycle in the past month, regardless of the purpose; Non-Cyclists are those who did not ride a bicycle at all in the past 12 months, and Potential Cyclists include those who rode a bicycle at least once in the past 12 months. In addition, 40 participants (5.5%) had disabilities, but not ones that might prevent them from cycling, and 37.4% of participants had previously been injured while cycling.

The questionnaire then asked participants to estimate how effective

Table 1
Sociodemographic characteristics of the sample.

Characteristics	Sample% (Auckland%)	Characteristics	Sample% (Auckland%)
Age (in years)		**Ethnicity**	
18–20	5.1 (not reported)	Māori	10.5 (11.5)
21–30	35.5 (20.5)	Pacific peoples	21.9 (15.5)
31–40	25.3 (18.8)	Asian	18 (28.2)
41–50	14.9 (17)	MELAA*	1.4 (2.3)
51–60	9.3 (15.7)	Indian	6.8 (not reported)
>60	9.9 (23)	European/NZ European	39.1 (53.5)
Gender		Other ethnicities	2.2 (1.1)
Men	52.8 (49)		
Women	46.3 (51)		
Diverse	0.8 (not reported)	**Personal annual income (NZD)**	
Highest completed degree		No income	7.3 (8.7)
High School or below	34.1	<30 K	15.8 (36.8)
Undergrad degree	52.4	30 K-70 K	38.2 (34.1)
Master's degree/	13.5	70 K-100 K	23.2 (10.3)
Postgraduate		>100 K	15.6 (9.5)
Employment situation		**Car access in the household**	
Not employed	12.7	Yes	92.4
Part-time employed	13.3	No	7.6
Full-time employed	62.4		
Homemaker	5.7		
Retired	5.9		

* MELAA: Middle Eastern/Latin American/African.

Table 2
Cycling profile of the study participants.

Characteristics	%	Characteristics	%
Access to a bicycle at home		**Cycling purpose**	
Yes	55.6	Commuting	9.7
No	44.4	Short trips	26.5
Average bicycle usage (per week)		Recreation/exercise	63.7
0 times	23.5	**Average daily bicycle usage** (time)	
1–3 times	64.4	<15 mins	26.6
4–5 times	8.3	15–30 mins	47.1
>5 times	3.8	31–60 mins	20.8
Bicycle user type	>60 mins	5.5	
Non-cyclists	37	**Cycling injuries**	
Regular cyclists	39.7	Yes	37.4
Potential cyclists	23.3	No	62.6
Bicycle sharing ever used		**Bicycle sharing user type**	
Yes	35.4	Non-cyclists	7.4
No	64.6	Regular cyclists	56.4
		Potential cyclists	36.2

each of the cycling initiatives (37 items) were in encouraging them, individually, to cycle. The questions were divided into four categories (named 'constructs') as shown in Table 3: Infrastructure (IN), Bicycle Promotion (BP), Cycling Safety (CS), and Discourage Car Usage (DC), with the division not visible to the respondents in order to avoid any possible bias arising due to the label used. The cycling initiatives and the categorisation were adopted based on the findings from a recent in-depth qualitative study in Auckland, New Zealand (Jahanshahi et al., 2023).

Perceived effectiveness was estimated on a five-point Likert scale ranging from 'very low' to 'very high'. In the subsequent analysis, numerical values were assigned to each point on the scale, ranging from 1 for 'very low' through to 5 for 'very high'. While there are various Likert scales that could be used in order to measure perceptions of effectiveness, this study used the aforementioned five-point Likert scale following recent studies on perceived effectiveness and in the field of transportation (Fu et al., 2020; Kallbekken et al., 2013; Nag and Goswami, 2019; Mayer et al., 2012).

2.2. Data analysis

The reliability of the questionnaire was examined by exploring the ranges of Cronbach's α coefficients. Then, in order to check the validity of the convergence and divergence of the model's items a confirmatory factor analysis was conducted. To compare the effectiveness of the constructs, a repeated measure ANOVA was used similar to that undertaken by Fishman et al. (2014). In order to compare the effectiveness of factors within each construct of the model, a Friedman Test was conducted. The relationship between the perceived effectiveness of the constructs and the participants' socio-demographic characteristics (including age, income, gender, education, cycling user type, and ethnicity) were explored by conducting MANOVA, univariate tests and pairwise comparison. The relationship between the socio-demographic characteristics of the study participants and the effectiveness of the cycling initiatives themselves was investigated by conducting a Classification and Regression Tree (CART) analysis. This method classified the respondents into different groups based on their rating of the effectiveness of cycling initiatives. For this purpose, age, income, gender, education, cycling user type, and ethnicity were all considered.

3. Results

3.1. Descriptive analysis

This section presents the descriptive statistics for cycling initiatives.

Table 3
Questionnaire items for cycling initiatives constructs.

Code	Cycling initiatives	Target groups and resulting beneficiaries from the viewpoint of experts (Jahanshahi et al., 2023)
	Infrastructure	
IN1	Improving the quantity and quality of cycle lanes	Higher income people with higher level of education who are traveling to or from the isthmus or that live in the area
IN2	Reducing traffic speed in neighbourhoods	Less confident cyclists
IN3	Public parking facilities for bicycles	Cyclists, potential cyclists, and non-cyclists
IN4	Public parking facilities for bicycles (secured with CCTV)	Cyclists
IN5	Bicycle security initiatives, such as serial number registration and the opportunity to swap your bicycle lock for a better, more secure, one.	Cyclists
IN6	Availability of public showers, changing rooms, and lockers at the end of your trip	Cyclists
IN7	Adding protection such as kerbs or dividers to existing cycleways in order to separate them from road traffic.	Cyclists, potential cyclists, and people who are more risk-averse
IN8	Implement more bus lanes. Note that cyclists can travel in bus lanes.	Cyclists
	Bicycle promotion	
BP1	Pay-as-you-go bike share schemes (ONZO, Lime, Jump, etc.)	People who commute in CBD area and areas that the company can make money.
BP2	Ability to carry your bicycle onto buses, trains, and ferries.	Cyclists and especially for those who cycle a long distance and are willing to change their mode of transport
BP3	E-bike trial and loan schemes	Low to middle income people, people who know how to cycle but less experienced
BP4	Free bike safety checks and minor maintenance work	Cyclists
BP5	Support for community groups with the design, delivery and/or funding of their ideas for promoting cycling in their neighbourhoods.	Everyone
BP6	Support the expansion of community bike hubs at key locations across the region to divert bikes from landfill, carry out basic repairs to make them safe and usable and distribute low-cost bikes to local communities.	Everyone, regardless of having a bike. It can also help to address some of the socioeconomic barriers
BP7	Provide support to cycling-focused community groups to empower and grow (such as supporting their cycling skills events, bicycle maintenance events, etc).	Cycling enthusiast or advocate
BP8	Bike challenge: A challenge to encourage cycling where you use an app on your phone to record when and how far you cycle. The more you cycle the more points you score.	Younger people, cyclists, fitter people, and people with access to mobile phone and internet services
BP9	Community Bike Fund for non-profit groups to apply for ideas to promote cycling in their neighbourhoods.	Lower income communities
BP10	Auckland Transport mobile app for planning your cycling journey. The app will suggest the best cycling routes for your journey.	Everybody with access to technology (mobile phone, internet, etc.). Children and elderly would be disadvantaged people
BP11	Cycling skills training in schools when you were growing up or for your children (You need your own bike).	Kids and especially targets low socioeconomic statuses
BP12	A container full of bikes in a school with additional training for teachers	Kids

(continued on next page)

Table 3 (*continued*)

Code	Cycling initiatives	Target groups and resulting beneficiaries from the viewpoint of experts (Jahanshahi et al., 2023)
	Infrastructure	
	for how to teach kids how to ride (when you were growing up or for your children).	
BP13	Kids Learn-to-Ride drop-in events, adult bike skills courses, and basic bike maintenance courses (free events).	Less confident cyclists or people who never ridden a bike before but own a bike
BP14	Improving signage and pavement markings to help you find cycleways and cycle routes.	Cyclists and potential cyclists
BP15	Residential door knocking journey planning (coming to you for asking about your journeys and offer plans)	Everyone
BP16	Offering travel planning and a wide variety of incentives through work, to get staff traveling to work by bicycle, (such as providing an advance on your wages or salary to buy a bike, discounts for buying a bicycle, flexible times for arriving at work, etc.)	Everyone who works
BP17	Guided e-bike tours for the public and businesses.	Everyone
BP18	Events to improve awareness of, and to celebrate, new and existing cycling infrastructure.	Cyclists
BP19	Consultation with the community and listening to people before designing bike infrastructure in their neighbourhoods.	Everyone
	Cycling Safety	
CS1	Enforcement to keep cycling infrastructure and facilities clear of obstructions (e.g. bins and other obstacles)	Cyclists
CS2	Road rule changes to improve cycling safety (e.g. automatic liability for hitting cyclists)	Cyclists
CS3	Vehicle safety features that reduce the injury to cyclists if hit by a vehicle.	Cyclists
CS4	Road speed limit enforcement to promote road safety.	Everyone
CS5	Campaigns (via social media, advertising and events) that normalise bicycle usage in the minds of drivers – so that they respect cyclists and are happy to share the road with them.	Cyclists
CS6	Lighting improvements on cycleways, particularly in parks and off-road areas	Women, younger/elderly, or people who feel more vulnerable
	Discouraging car usage	
DC1	Parking management to ban on-street car parking in certain areas.	Everyone
DC2	Congestion charging in areas with other transport options, resulting in reduced traffic flows	Car users
DC3	Increase the cost to park in areas that could easily be accessed by cycling, resulting in reduced traffic in these areas.	Car users
DC4	Increase the cost of owning a car and subsidise bike ownership.	Car users

The mean, median, standard deviation and, for each initiative, the percentage of responses in each effectiveness category are included in Table 4. The initiatives in the Cycling Safety and Infrastructure constructs had the highest mean scores, implying respondents believe that these cycling initiatives are more effective in encouraging cycling from an individual perspective. Two initiatives within the Cycling Safety construct were rated the most highly (high mean scores): vehicle safety features that reduce the injury to cyclists (CS3) and lighting improvements on cycleways, particularly in parks and off-road areas (CS6), while residential door knocking journey planning (BP15) under the Bicycle Promotion construct and increasing the cost of owning a car and subsidising bike ownership (DC4) under the Discourage Car Usage construct were rated as the least effective on the basis of low mean scores. This section shows that Cycling Safety, in particular, is considered to be effective in encourage cycling.

3.2. *Measurement steps*

3.2.1. *Reliability*

Assessing the research instrument reliability is an important phase in any study as it shows the extent to which the study is able to be replicated; studies exploring perceptions are no exception (Drost, 2011). Consequently, this section analyses the reliability of the studied constructs. Since the cycling initiatives were clustered into four constructs, in line with the previous qualitative study, a confirmatory factor analysis (CFA) was applied in order to guarantee the factors' convergent and discriminant validity (Byrne, 2012; Churchill, 1979). In this regard, a CFA was applied to the initiatives, as illustrated in Table 5. All of the initiatives resulted in valid loading factors above the threshold value of 0.4 recommended by Field (2013) and were, therefore, retained. Then, Cronbach's α coefficients of the constructs were estimated, with all exceeding the 0.6 threshold, indicating an acceptable range of reliability (Hair et al., 2010).

The relationships between pairs of constructs were then investigated, as shown in Table 6. Following Cohen (1988), all of the constructs are highly positively correlated (significant at the 0.01 level). The positive correlation coefficients suggest that, typically, those who perceive the effectiveness of one of the constructs as being high also perceive the effectiveness of other constructs as high. In terms of the range, the strongest correlation is between Infrastructure and Bicycle Promotion (0.767) and the weakest correlation is between Infrastructure and Discouraging Car Usage (0.561).

3.2.2. *Constructs effectiveness comparison*

A relative comparison of the effectiveness of the constructs on the basis of the initiatives within, in terms of encouraging bicycle usage, is presented in this section. The effectiveness of the constructs was compared using a repeated measures ANOVA analysis, resulting in a Wilks' Lambda $F(3,639) = 63.159$ with a significance value of $p < 0.001$. Results of the Greenhouse-Geisser test and Mauchly's Test of Sphericity both indicate significance levels of <0.001, which shows that the constructs' differences are reliable, allowing the constructs to be compared. This was carried out using pairwise comparisons with a Bonferroni correction. Table 8 presents the results of this analysis. It reveals that initiatives under the Discouraging Car Usage construct are less effective compared to other constructs with the most effective being Cycling Safety, Infrastructure and the Bicycle Promotion.

3.2.3. *Initiatives effectiveness comparison*

This section presents the perceived effectiveness of each cycling initiative in terms of encouraging bicycle usage, and compares them within each construct. A non-parametric Friedman Test was conducted to compare the perceived effectiveness of the initiatives in each construct. The reported Chi-square values were $\chi^2(7, 726) = 121.945$, $\chi^2(18, 718) = 730.475$, $\chi^2(5, 721) = 103.143$, and $\chi^2(3, 726) = 163.883$ for Infrastructure, Bicycle Promotion, Cycling Safety, and Discouraging

Table 4
Descriptive statistics for cycling initiatives.

Question	Mean	Median	Std. Deviation	Very low %	Low %	Moderate %	High %	Very high %
IN1	3.06	3.00	1.112	10.2	16.9	40.4	21.2	11.2
IN2	3.00	3.00	1.132	9.8	22.8	36.3	19.4	11.6
IN3	3.10	3.00	1.041	6.7	19.6	40.9	22.8	10.0
IN4	3.24	3.00	1.114	7.9	14.9	35.9	27.3	14.0
IN5	3.10	3.00	1.101	8.6	19.0	37.3	23.8	11.2
IN6	2.98	3.00	1.092	10.4	21.6	35.8	24.3	7.9
IN7	3.33	3.00	1.079	5.3	15.5	35.6	28.0	15.6
IN8	3.08	3.00	1.086	8.8	18.8	38.4	24.0	10.1
BP1	2.73	3.00	1.117	15.8	25.8	34.7	17.2	6.4
BP2	3.13	3.00	1.119	9.6	16.7	36.9	25.2	11.6
BP3	2.94	3.00	1.082	10.5	22.0	38.2	21.3	7.9
BP4	3.21	3.00	1.061	5.2	19.5	37.5	24.9	12.9
BP5	3.04	3.00	1.033	8.1	19.3	41.1	23.6	7.9
BP6	3.08	3.00	1.009	7.3	17.4	42.8	24.8	7.8
BP7	3.05	3.00	1.004	7.2	18.9	43.0	23.5	7.4
BP8	2.91	3.00	1.065	10.7	22.8	38.0	21.9	6.7
BP9	2.97	3.00	1.041	9.6	20.2	41.3	22.0	7.0
BP10	3.15	3.00	1.043	7.0	18.1	37.3	28.5	9.1
BP11	3.20	3.00	1.062	6.8	16.4	37.5	28.0	11.2
BP12	3.20	3.00	1.087	7.1	17.1	37.0	26.2	12.6
BP13	3.25	3.00	1.039	6.3	13.9	40.2	27.9	11.7
BP14	3.26	3.00	1.034	5.9	15.5	36.4	31.6	10.7
BP15	2.51	3.00	1.104	22.5	25.7	33.6	14.4	3.8
BP16	2.90	3.00	1.066	11.6	20.8	39.9	21.2	6.4
BP17	2.82	3.00	1.083	12.3	25.3	36.5	19.3	6.6
BP18	2.95	3.00	1.021	8.2	23.1	40.4	21.6	6.7
BP19	3.20	3.00	1.020	5.9	16.0	40.7	27.0	10.3
CS1	3.20	3.00	1.003	5.8	15.1	41.8	27.6	9.7
CS2	3.23	3.00	1.088	7.3	15.0	38.4	25.9	13.4
CS3	3.34	3.00	1.033	4.8	13.6	38.2	29.4	14.0
CS4	3.20	3.00	1.071	7.0	16.2	39.2	25.4	12.2
CS5	3.04	3.00	1.067	9.1	19.2	39.3	23.8	8.7
CS6	3.38	3.00	1.039	4.7	12.7	38.0	29.2	15.4
DC1	3.02	3.00	1.164	12.5	17.7	36.6	21.7	11.5
DC2	2.92	3.00	1.070	11.6	19.3	41.4	20.5	7.1
DC3	2.71	3.00	1.166	19.0	22.7	34.0	17.1	7.1
DC4	2.51	3.00	1.212	28.6	18.7	31.5	15.8	5.5

car usage respectively, meaning that a comparison of the initiatives of all of the constructs was able to be undertaken ($p < 0.005$). As shown in Figs. 1–4, adding protection to existing cycleways and improving signage and pavement markings were the initiatives with the highest mean rankings within the Infrastructure and Bicycle Promotion constructs, respectively. The availability of public showers, changing rooms, and lockers at the end of trip were ranked as the lowest in the Infrastructure construct. Residential door knocking journey planning was rated as the lowest within the Bicycle Promotion construct. Within Cycling Safety, lighting improvements on cycleways was considered to be the most effective, while campaigns aimed at normalising bicycle usage in the minds of drivers was rated the lowest. Regarding Discouraging Car Usage, the initiative rated as the highest was parking management to ban on-street car parking in certain areas, whereas increasing the cost of owning a car and subsidising bike ownership were considered to be the least effective.

3.2.4. *Relationship between constructs and sociodemographic characteristics*

In this section, the relationship between the perceived effectiveness of constructs and sociodemographic characteristics (age, income, gender, education, cycling user type, and ethnicity) was estimated. A MANOVA analysis was conducted for this purpose. A Levene's test was conducted to evaluate the equality of error variances, and a Box's test was conducted to assess the equality of covariance matrices. Then, to explore significant differences between the ratings of constructs amongst the various socio-demographic groups, a Wilks' Lambda test was conducted. The results indicate that the requirements were not met for gender, income, or educational levels. Thus, only the remaining sociodemographic characteristics (age, ethnicity, and bicycle user type) are considered for this purpose.

Following this, a univariate test is used to illustrate which constructs differ amongst socio-demographic groups. Finally, a pairwise comparison is used to revealed how demographic characteristics are related to the perceived effectiveness of the constructs.

3.2.4.1. Age levels. In relation to age, the results of the aforementioned tests show that a MANOVA is able to be used reliably (SIG < 0.05). In order to determine the significance of the MANOVA a Wilks' Lambda test was then conducted. Results indicate that there is a statistically significant difference, based on age levels, in all of the constructs ($F = 6.13$, $p < 0.05$; Wilks' $\Lambda = 0.896$, partial $\eta^2 = 0.041$).

Univariate tests were conducted to ascertain the influence of age on the perceived effectiveness of the constructs. As shown in Table 9, age has a statistically significant influence on the perceived effectiveness of initiatives within the Infrastructure ($F = 3.55$; $p < 0.05$; partial $\eta^2 = 0.024$), Bicycle Promotion ($F = 8.03$; $p < 0.05$; partial $\eta^2 = 0.053$), and Discouraging Car Usage ($F = 11.57$; $p < 0.05$; partial $\eta^2 = 0.036$) constructs, whereas no significant influence was found within the Cycling Safety ($p > 0.05$) construct. To compare the effect of age on the perceived effectiveness of the Infrastructure, Bicycle Promotion, and Discouraging Car Usage construct scores, pairwise comparisons were used. The results suggest that older participants, in general, reported lower levels of effectiveness with respect to the significant constructs. Fig. 5 illustrates the different levels of perceived effectiveness of the constructs by different age groups.

3.2.4.2. Bicycle Usership. In relation to the Bicycle Usership category,

Table 5
Factor loadings and Cronbach's α coefficients of the constructs.

Constructs	Cycling initiatives	Factors Loading	Cronbach's α	Mean	Standard deviation
Infrastructure			0.886		
	IN1	0.717		3.06	1.108
	IN2	0.701		3.00	1.132
	IN3	0.781		3.10	1.042
	IN4	0.808		3.25	1.109
	IN5	0.795		3.10	1.101
	IN6	0.659		2.98	1.091
	IN7	0.767		3.33	1.080
	IN8	0.744		3.08	1.088
Bicycle Promotion			0.939		
	BP1	0.600		2.72	1.112
	BP2	0.676		3.13	1.115
	BP3	0.645		2.94	1.078
	BP4	0.687		3.21	1.055
	BP5	0.758		3.04	1.025
	BP6	0.736		3.09	1.005
	BP7	0.764		3.05	1.000
	BP8	0.718		2.91	1.065
	BP9	0.778		2.96	1.040
	BP10	0.727		3.15	1.042
	BP11	0.675		3.20	1.058
	BP12	0.673		3.20	1.085
	BP13	0.721		3.25	1.031
	BP14	0.710		3.26	1.036
	BP15	0.596		2.50	1.099
	BP16	0.685		2.90	1.066
	BP17	0.655		2.82	1.080
	BP18	0.740		2.95	1.011
	BP19	0.601		3.19	1.023
Cycling Safety			0.873		
	CS1	0.738		3.20	1.003
	CS2	0.805		3.22	1.086
	CS3	0.827		3.34	1.034
	CS4	0.814		3.19	1.070
	CS5	0.757		3.03	1.065
	CS6	0.753		3.38	1.041
Discouraging Car Usage			0.828		
	DC1	0.785		3.02	1.164
	DC2	0.833		2.92	1.066
	DC3	0.868		2.71	1.165
	DC4	0.768		2.50	1.209

Table 6
Correlations between the constructs.

Constructs	A	B	C	D
A: Infrastructure		1		
B: Bicycle Promotion	0.767**	1		
C: Cycling Safety	0.709**	0.761**	1	
D: Discouraging Car Usage	0.561**	0.641**	0.612**	1

**Correlation is significant at the 0.01 level (2-tailed).

the results of the aforementioned tests show that a MANOVA is able to be used reliably (SIG < 0.05). In order to determine the significance of the MANOVA a Wilks' Lambda test was then conducted. Results indicate that there is a statistically significant difference, based on Bicycle Usership, in all of the constructs ($F = 7.63$, $p < 0.05$; Wilks' $\Lambda = 0.976$, partial $\eta^2 = 0.057$).

Univariate tests were conducted to ascertain the impact of Bicycle Usership on the perceived effectiveness of the constructs. As shown in Table 10, Bicycle Usership has a statistically significant influence on the perceived effectiveness of initiatives within the Infrastructure ($F = 15.01$; $p < 0.05$; partial $\eta^2 = 0.043$), Bicycle Promotion ($F = 24.54$; $p < 0.05$; partial $\eta^2 = 0.068$), Discouraging Car Usage ($F = 16.48$; $p < 0.05$; partial $\eta^2 = 0.058$), and Cycling Safety ($F = 8.61$; $p < 0.05$; partial $\eta^2 = 0.025$) constructs. To evaluate and compare the influence of Bicycle Usership on the perception of the effectiveness of the Bicycle Promotion, Cycling Safety, Infrastructure, and Discouraging Car Usage constructs, a pairwise comparison was used. Results show that people who cycle more report higher levels of effectiveness with respect to all of the constructs. Fig. 6 illustrates the different levels of perceived effectiveness of the constructs by different bicycle user types.

3.2.4.3. Ethnicity. For ethnicity, the results of the aforementioned tests show that a MANOVA is able to be used reliably (SIG < 0.05). In order to determine the significance of the MANOVA a Wilks' Lambda test was then conducted. Results indicate that there is a statistically significant difference, based on ethnicity, in all the constructs ($F = 3.31$, $p < 0.05$; Wilks' $\Lambda = 0.823$, partial $\eta2 = 0.032$).

Univariate tests were conducted to ascertain the impact of ethnicity on the perceived effectiveness of the constructs. As shown in Table 11, ethnicity has a statistically significant influence on the perceived effectiveness of initiatives within the Bicycle Promotion ($F = 4.13$; $p < 0.05$; partial $\eta2 = 0.044$) and Discouraging Car Usage ($F = 6.26$; $p < 0.05$; partial $\eta2 = 0.048$) constructs, whereas no significant influence was found within the Cycling Safety or Infrastructure ($p > 0.05$ for both) constructs. A pairwise comparison was used to evaluate and compare the effect of different ethnicities on Bicycle Promotion and Discouraging Car Usage. Results show that Māori and Pacific participants consider initiatives within both the Bicycle Promotion and Discouraging Car Usage constructs as more effective compared with European and New Zealand European participants. Fig. 7 illustrates the different levels of perceived effectiveness of the constructs by different ethnicities.

3.2.5. Relationship between initiatives and sociodemographic characteristics

In this section, we identify the population groups which significantly differ in terms of their perceived effectiveness of the individual cycling initiatives, independent of the constructs to which they were assigned, using a CART analysis. A CART analysis was implemented for all 37 of the initiatives. The key results are included in Table 12. However, for the sake of brevity, the CART analysis figures and tables are not included.

Overall, the CART analysis identified a significant number of cycling initiatives where age was a determining factor in terms of clustering the perceived effectiveness data. In all of these cases, the results indicate that as participants get older, the initiatives are perceived as being less effective. A similar outcome was reported for numerous other initiatives, as listed in Table 12, whereby older participants, specifically people older than 50 or 60, reported lower levels of effectiveness compared to other age groups. Also, the analyses only identified a limited number of cycling initiatives where gender, educational levels, and income levels were a determining factor in terms of clustering the perceived effectiveness data. Men reported higher levels of effectiveness, compared with women for implementing more bus lanes, whereas women reported higher levels of effectiveness compared to men for offering travel planning and a wide variety of incentives through work, to get staff traveling to work by bicycle. People with personal income levels lower than 100 K NZD reported higher levels of perceived effectiveness for bicycle security initiatives, support for community groups with the design, delivery and/or funding of their ideas for promoting cycling in their neighbourhoods, and the Auckland Transport mobile app for planning your cycling journey, compared with people with higher income levels. People with a high school degree reported lower levels of perceived effectiveness than people with a university degree for cycling initiatives, including improving the quantity and quality of cycle lanes, public parking facilities for bicycles, e-bike trial and loan schemes, and events to improve awareness of, and to celebrate, new and existing

Table 8
Pairwise comparisons for constructs.

Constructs (I)	Constructs (J)	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
Infrastructure	Bicycle Promotion	0.085*	0.02	000	0.032	0.137
	Cycling Safety	−0.123*	0.023	000	−0.184	−0.062
	Discouraging Car Usage	0.264*	0.028	000	0.178	0.325
Bicycle Promotion	Infrastructure	−0.085*	0.02	000	−0.137	−0.032
	Cycling Safety	−0.208*	0.02	000	−0.261	−0.155
	Discouraging Car Usage	0.172*	0.024	000	0.104	0.23
Cycling Safety	Infrastructure	0.123*	0.023	000	0.062	0.184
	Bicycle Promotion	0.208*	0.02	000	0.155	0.261
	Discouraging Car Usage	0.381*	0.026	000	0.307	0.442
Discouraging Car Usage	Infrastructure	−0.264*	0.028	000	−0.325	−0.178
	Bicycle Promotion	−0.172*	0.024	000	−0.23	−0.104
	Cycling Safety	−0.381*	0.026	000	−0.442	−0.307

Based on estimated marginal means.
*. The mean difference is significant at the 0.05 level.
b. Adjustment for multiple comparisons using Bonferroni correction.

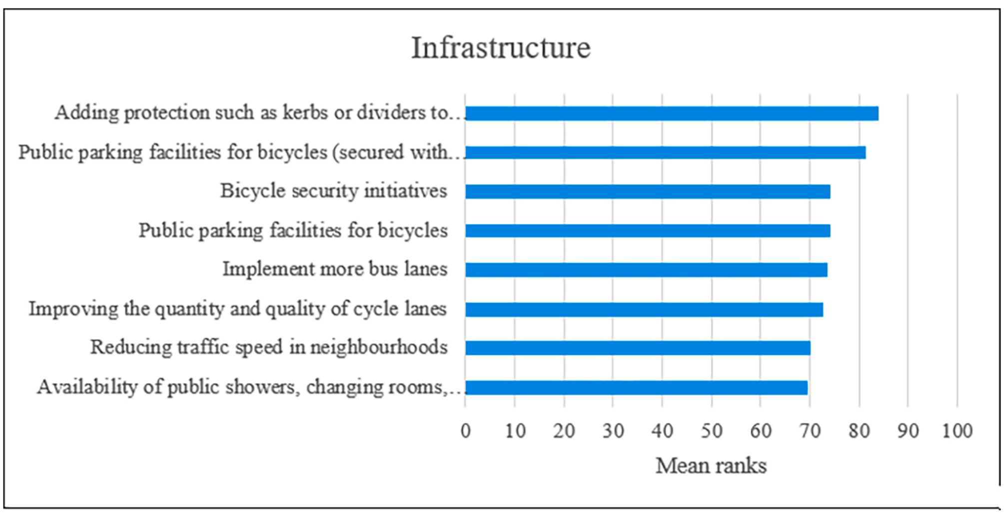

Fig. 1. Comparison of initiatives within the Infrastructure construct.

cycling infrastructure. Analyses identified a significant number of cycling initiatives where bicycle user type and ethnicity were a determining factor in terms of clustering the perceived effectiveness data.

4. Discussion

This study highlighted people's perceptions of cycling initiatives and the relationship between socio-demographic characteristics and those perceptions. It is noted, however, that perceptions and reality are not always aligned. For example, the perception of safety, how safe an individual feels when using the cycling network, could differ from objective measures of safety on the cycling network (Jahanshahi et al., 2020). However, as people's perceptions are what drive behaviour, it can be argued that the measure is appropriate in terms of encouraging more people to cycle.

The effectiveness of cycling initiatives were investigated from the viewpoint of different population groups in Auckland, New Zealand. The study considered regular cyclists, potential cyclists and non-cyclists, as well as representative demographic groups, to provide a comprehensive understanding of the association between the perceived effectiveness of cycling initiatives and socio-demographic characteristics, including income level, gender, age, educational level, ethnicity, and bicycle user type, both on terms of the individual initiatives and also when grouped (analysed as constructs). The classification method for bicycle user type in this study was based on the method proposed by Félix et al. (2017) and, subsequently, adopted in other studies (Wang and Akar, 2018; Félix et al., 2019). There are other classifications that could have been used, such as that introduced by Dill and McNeil (2013), however, the simplicity of the chosen method was attractive given the length of the questionnaire for this study. Future studies could benefit from sensitivity analyses using different classification methods for cyclists.

Descriptive analyses indicate that initiatives within the Cycling Safety construct are considered to be the most effective, with lighting improvements and vehicle safety features rated as the most effective amongst all of the cycling initiatives. In contrast, initiatives within the Discouraging Car Usage construct were considered to be the least effective. All four of the constructs were found to be strongly correlated, indicating that participants who rate any of the initiatives highly tend to also rate others highly.

Next, analyses were conducted to observe the ranking of the effectiveness of initiatives within each construct. The most effective initiative within the Infrastructure construct was adding protection such as kerbs

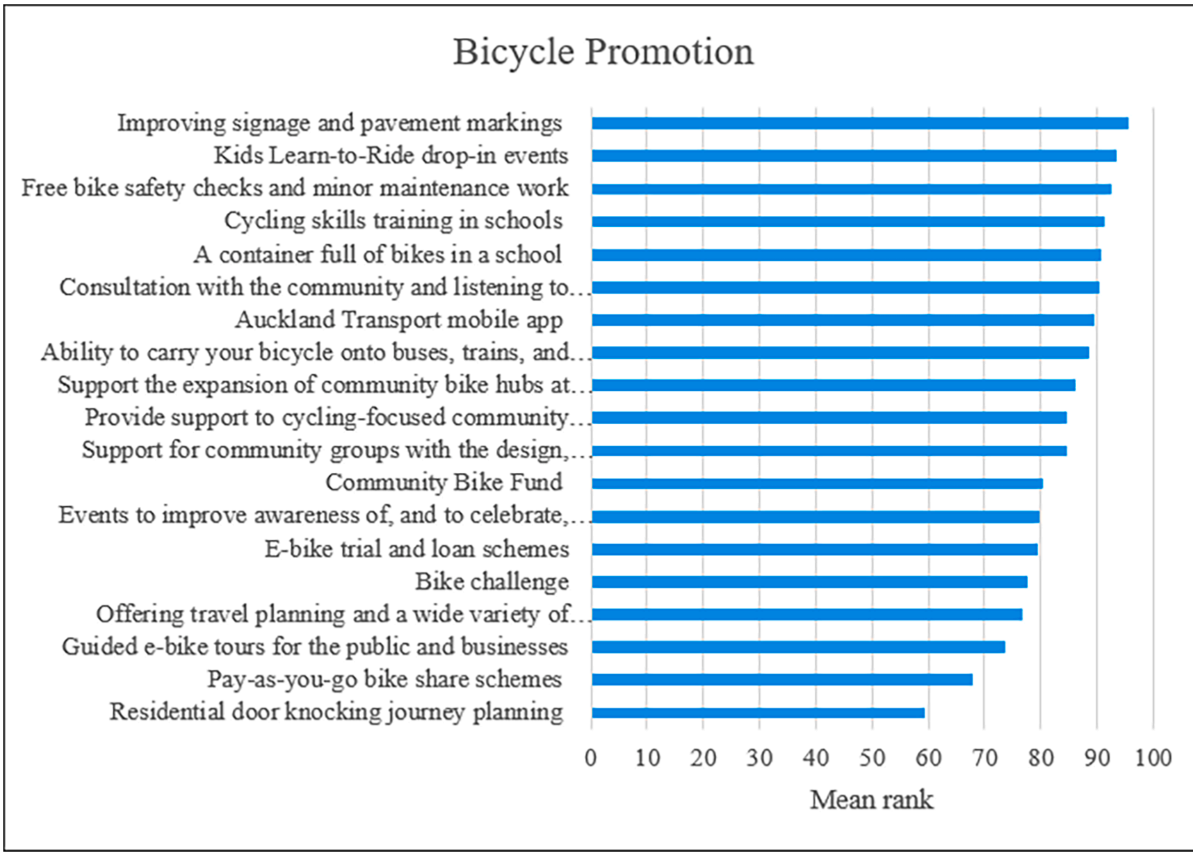

Fig. 2. Comparison of initiatives within the Bicycle Promotion construct.

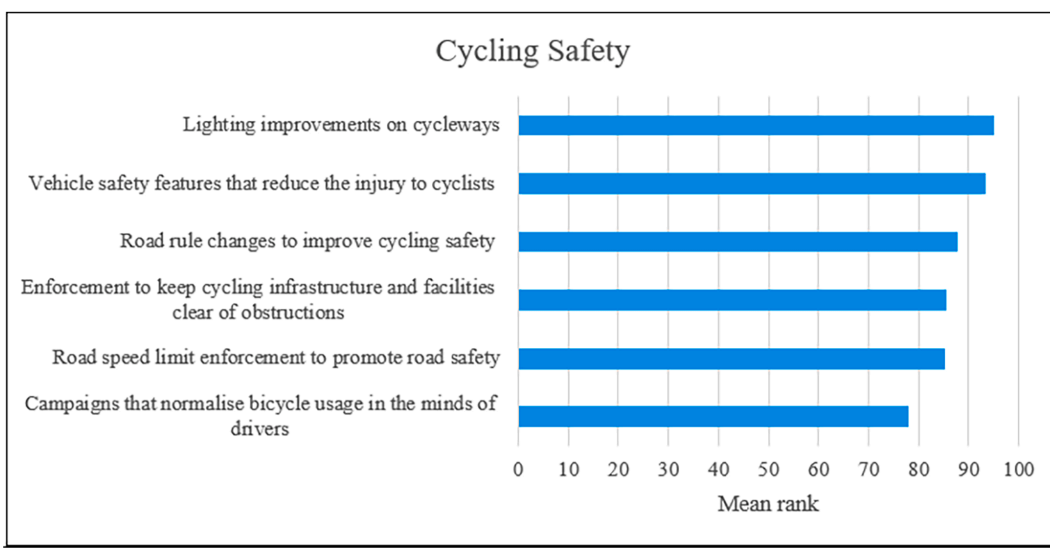

Fig. 3. Comparison of initiatives within the Cycling Safety construct.

or dividers to existing cycleways. This initiative is also indirectly related to cycling safety and indicates that infrastructure provisions that increase cycling safety are perceived as being more effective than others. Regarding the effectiveness of initiatives under the Bicycle Promotion construct, improving signage and pavement markings were rated the highest. This initiative is also indirectly related to cycling safety and further emphasises that cycling safety is one of the most important factors. Among the initiatives in Cycling Safety, lighting improvements on cycleways was reported as the most effective initiative, as expected given that it was the most effective initiative among all of the initiatives, as reported above. Based on a previous study, this initiative is particularly targeted at women, the elderly, children, and other vulnerable population groups. Initiatives within the Discouraging Car Usage construct were those that generally had the lowest perceived effectiveness, with the least effective initiative within this construct being increasing the cost of owning a car and subsidising bike ownership. It would appear, therefore, that participants do not see indirect cycling initiatives, such as those in the Discouraging Car Usage construct, as

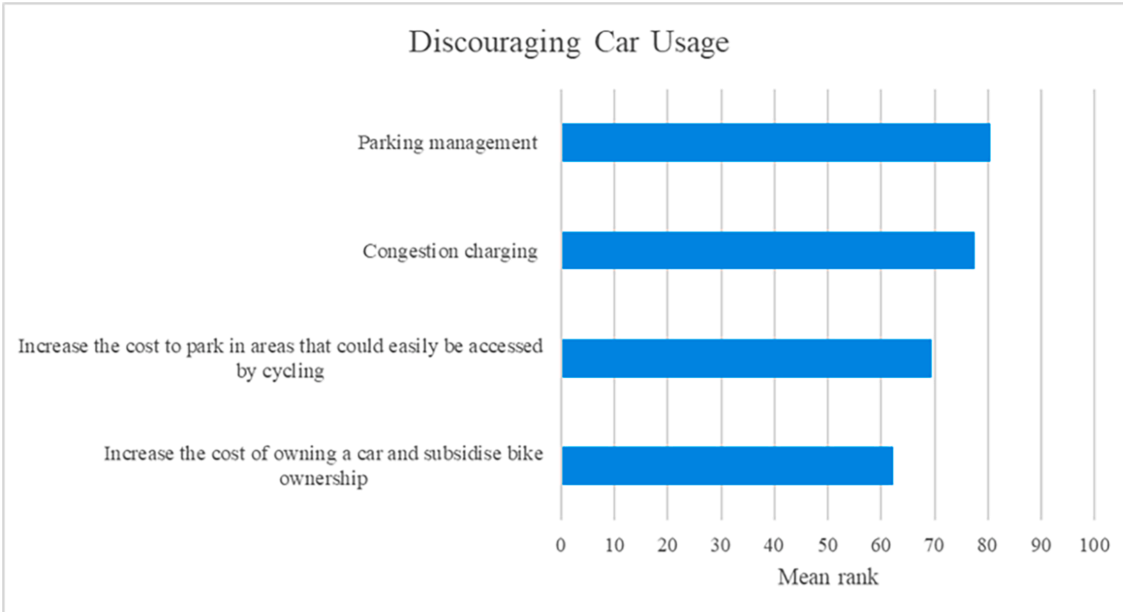

Fig. 4. Comparison of initiatives in the Discouraging Car Usage construct.

Table 9
Univariate tests for age levels.

	Mean Square	F	Sig.	Partial Eta Squared
Infrastructure	2.330	3.557	0.003	0.024
Bicycle Promotion	4.123	8.038	0.000	0.053
Cycling Safety	0.741	1.100	0.359	0.008
Discouraging Car Usage	7.232	11.578	0.000	0.036

Table 10
Univariate tests for Bicycle Usership.

	Mean Square	F	Sig.	Partial Eta Squared
Infrastructure	9.396	15.015	0.000	0.043
Bicycle Promotion	12.438	24.547	0.000	0.068
Cycling Safety	5.759	8.617	0.000	0.025
Discouraging Car Usage	11.142	16.486	0.000	0.058

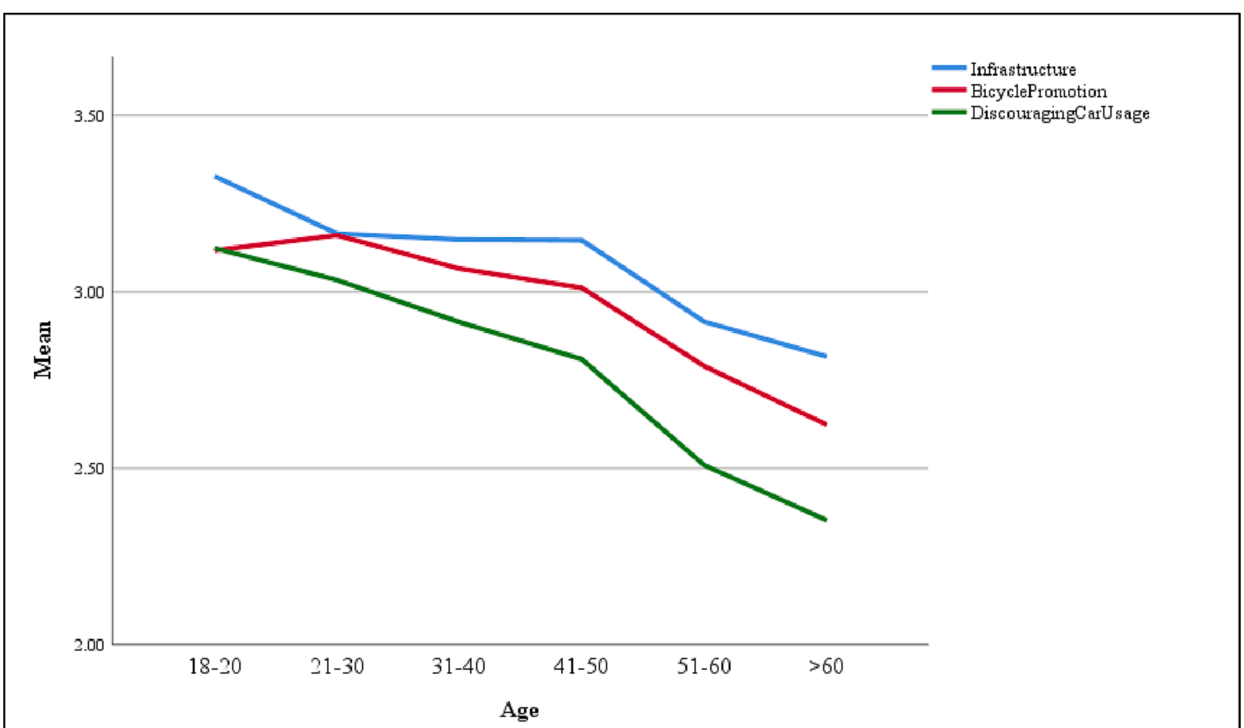

Fig. 5. Levels of perceived effectiveness of the constructs by different age levels.

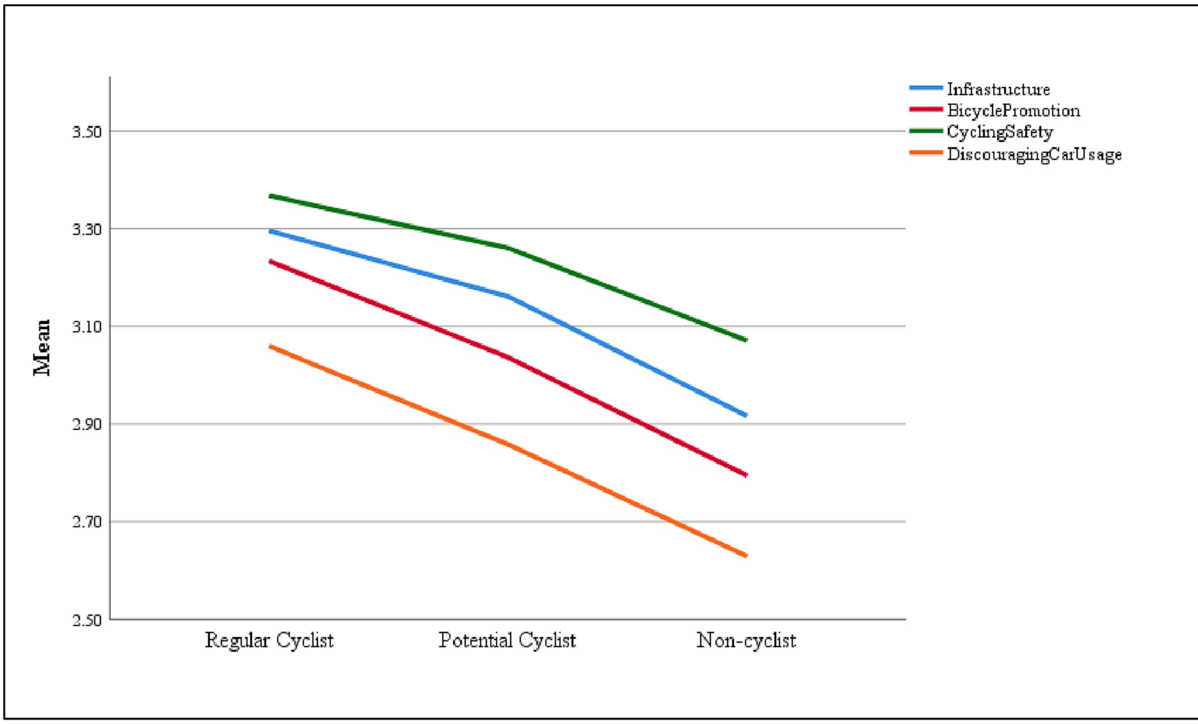

Fig. 6. Levels of perceived effectiveness of the constructs by different bicycle user type.

Table 11
Univariate tests for ethnicity.

	Mean Square	F	Sig.	Partial Eta Squared
Infrastructure	1.177	1.783	0.077	0.019
Bicycle Promotion	2.147	4.135	0.000	0.044
Cycling Safety	1.021	1.524	0.145	0.017
Discouraging Car Usage	3.742	6.261	0.000	0.048

being highly effective in encouraging bicycle usage.

Finally, a CART analysis was undertaken to highlight how different population groups differ in terms of their perceived effectiveness for each cycling initiative. This paragraph also shows the differences between experts' opinions about target groups and the perceived effectiveness from the viewpoint of participants. Younger people reported higher levels of effectiveness for bicycle sharing systems, which supports previous studies that showed that younger people are more interested in

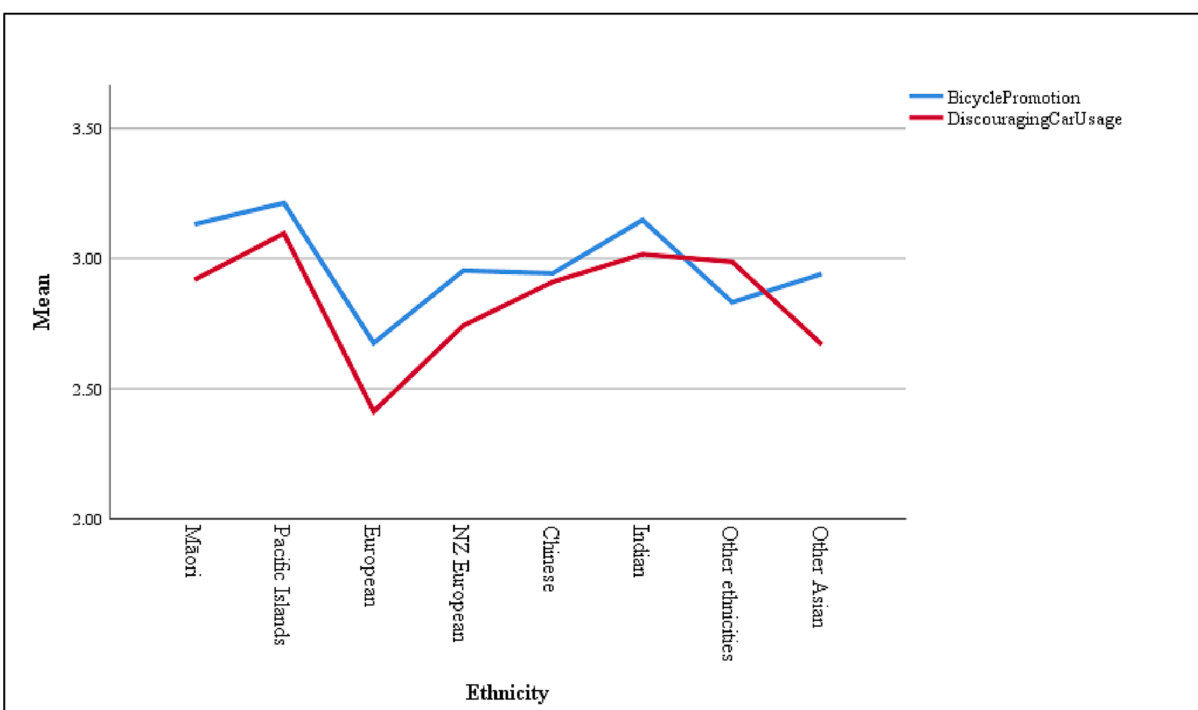

Fig. 7. Levels of perceived effectiveness of the constructs by ethnicity.

Table 12
Cycling initiatives and perceived effectiveness of population groups.

Socio-demographic characteristics	Target groups based on perceived effectiveness of population groups (CART analysis)	Cycling initiatives
Age	Participants aged 50 or younger reported higher levels of effectiveness compared to participants older than 50	IN5, IN7, IN8 BP3, BP4, BP7, BP12, BP13 BP18, CS3 DC2
	Participants aged 60 or younger reported higher levels of effectiveness compared to participants older than 60	BP6, BP10
	Younger people reported this initiative more effective compared to older people	BP1, BP2, BP5, BP8, BP9, BP15, BP16, BP17 DC1, DC3, DC4
Gender	Men reported higher levels of effectiveness compared to women	IN8
	Women reported higher levels of effectiveness compared to men	BP10
Education	Participants with a university degree reported higher levels of effectiveness compared to people with a high school degree	IN1, IN3 BP3, BP18
Ethnicity	Māori and Pacific people reported higher levels of effectiveness compared to other ethnicities	IN2, IN6, IN8 BP3, BP5, BP6, BP7, BP8, BP9, BP10, BP12, BP13, BP15, BP17, BP18 CS4 DC2, DC4
	Māori and Pacific people reported higher levels of effectiveness compared to other ethnicities, while Chinese and European people reported lower levels of effectiveness	BP1
Income Level	Participants with an income level of <100 K NZD reported higher levels of effectiveness compared with people with higher income levels	IN5 BP5, BP10
Bicycle User Type	Regular cyclists and potential cyclists reported higher levels of effectiveness compared to non-cyclists	IN1, IN3, IN4, IN5, IN8 BP1, BP2, BP8, BP9, BP10, BP12, BP13, BP14, BP16, BP17, BP18, BP19 CS1, CS2, CS3, CS4, CS5, CS6 DC1, DC3
	Regular cyclists reported higher levels of effectiveness compared to potential cyclists and non-cyclists	IN6, IN7 BP3, BP4, BP5, BP6, BP7, BP11, BP15 DC2, DC4

bicycle sharing systems than older people (Jahanshahi et al., 2019; Jahanshahi et al., 2020). One of the main reasons for this could be the fact that younger generations are more comfortable adopting and interacting with technology and mobile apps, compared to older generations. The ability to carry bicycles onto buses, trains, and ferries was another initiative that younger people reported as being more effectiveness compared to older people. This could be related to the fact that cyclists are usually younger people and that this initiative is also reported as effective for cyclists. Similarly, the Bike challenge was reported as more being effective for younger people. This is in line with the findings of the Jahanshahi et al. (2023) study where access to technology and technology acceptance were a key reason experts believed this initiative to be more attractive to younger people. Initiatives which discourage car usage by increasing the cost of owning and parking a car were also reported as being more effective for younger people. This could be because younger people (on average) have lower income levels and people with lower incomes are more price sensitive. Given the quantum of initiatives where younger people believe that the initiatives are more effective compared to older people, it is interesting to note that the experts in the Jahanshahi et al. (2023) study only identified lighting improvements on cycleways and the Bike Challenge as initiatives specifically targeting younger people.

The only initiative that was identified by experts in the Jahanshahi et al. (2023) study as specifically targeting women was lighting improvements on cycleways. Interestingly, this was not scored differently by men and women in this study, indicating that men are also safety conscious when deciding whether or not to cycle. Although safety-related initiatives traditionally target more vulnerable and risk-averse people, it seems that safety issues and concerns are very much generic. The Auckland Transport mobile app, which suggests the best/safest cycling routes for the journey, was reported as being more effective for women. This might be related to another aspect of safety where women are generally more risk-averse, and information regarding the safest cycling routes will alleviate that risk. In addition, opening more bus lanes, noting that cyclists can travel in bus lanes, were perceived as more effective by men. This could be related to women's safety concerns with respect to sharing road space with a bus.

Cycling initiatives identified by experts in the Jahanshahi et al. (2023) study as specifically targeting lower income groups, such as cycling skills training in schools, community Bike Fund for non-profit groups, the expansion of community bike hubs at key locations across the region, and E-bike trials and loan schemes, were not identified in the CART analysis. The findings of this study indicate that bicycle security initiatives were reported as being more effective for lower income groups. This could be because lower income groups are more concerned about losing their bicycle, due to the cost of replacement or not having insurance cover, and such security initiatives provide a level of assurance against theft.

In the Jahanshahi et al. (2023) study, experts did not identify any initiatives as specifically targeting ethnic groups. However, the current study showed that Māori and Pacific people reported higher levels of effectiveness with respect to a number of cycling initiatives compared to other ethnicities. The potential reasons for differences between Māori and Pacific people's and others perceived effectiveness is not entirely clear and further investigations need to be undertaken to discover the fundamental reasons for this. Given that Māori and Pacific people are considered to be disadvantaged population groups in terms of cycling benefits (Bassett et al., 2020; Shaw and Russell, 2017), cycling policies should attempt to address barriers to their bicycle use. The cycling initiatives reported in Table 12 that are more effective from the viewpoint of Māori and Pacific people will assist in this process.

In the Jahanshahi et al. (2023) study, experts identified numerous cycling initiatives that targeted current cyclists, and a similar outcome was expected in this study. Many of the cycling initiatives shown in Table 12 returned higher levels of effectiveness for regular cyclists or potential cyclists, compared with non-cyclists. Of concern is that none of the cycling initiatives were considered to be more effective by non-cyclists in comparison with potential cyclists and regular cyclists.

5. Conclusion

Based on the findings of this study, people with different socio-demographic backgrounds clearly have different perceptions of the effectiveness of cycling initiatives, with the effectiveness of cycling initiatives in Auckland more strongly related to factors such as bicycle user type, age, and ethnicity, compared to other sociodemographic characteristics. Overall, however, initiatives in the Cycling Safety construct were considered to be the most effective, with indirect cycling initiatives, such as those in the Discouraging Car Usage construct, being the least effective. In addition, many of the cycling initiatives were more attractive to population groups other than the intended target group.

Non-cyclists, along with older people and women – three groups associated with low cycling rates, consistently reported lower perceived effectiveness with respect to cycling initiatives. This suggests that cycling initiatives need to be more creative and targeted if these groups are to be given priority. In contrast, Māori and Pacific people, another group with a low cycling rate, reported higher levels of perceived effectiveness compared to others for many of the listed initiatives. This apparent contradiction requires further research in order to understand why Māori and Pacific reported lower bicycle usage rates, despite their higher perceptions of the effectiveness of many of the cycling initiatives. Interestingly, Māori and Pacific people reported higher levels of effectiveness for the majority of the initiatives in the Bicycle Promotion construct. Such initiatives include various forms of engagement and consultation with, as well as support for, communities. A better understanding of the social and spatial distribution of such events across Auckland may help understand if such promotions are reaching these target groups. The findings of this study could be used to provide better insights for policymakers and local governments, as well as the design of better strategies for improving cycling policies, initiatives, and investment in order to decrease inequity in cycling.

Finally, it should be noted that Auckland is young in terms of its cycling journey. With the lowest cycling rates among New Zealand cities, the primary aim is increasing bicycle use and facilitating the rapid uptake of cycling. In contrast, in places with high bicycle usage rates and an established cycling culture (such as in Amsterdam), there is more capacity to focus on issues such as equity. As Auckland matures in terms of its cycling journey, it is hoped that the findings in this paper will help shape equitable policy and funding decision-making, resulting is fair outcomes for all.

6. Limitations

A potential limitation of any study of this type is the risk of bias due to self-selection, as well as respondents tending towards providing socially acceptable answers. Such self-selection is unavoidable in that the participants are those who received the online questionnaire and decided to complete it. Another limitation of this study might be a selection effect due to the language barrier, given that the questionnaire was only provided in English.

In addition, this study is limited to the previously identified cycling initiatives in Auckland, and future studies could consider additional or alternative cycling initiatives based on their case study. This, along with the fact that the participants are a sample of the Auckland population, the results of this study cannot *a priori* be easily generalized. However, it is anticipated that the results could be applicable to other medium-sized multicultural cities in similar contexts (geographical, economic, and socio-cultural) worldwide.

Another limitation of this study is the fact that the frequency of cycling was the only considered factor for the classification of cyclists. However, following recent studies by An et al., (2022) and Ton et al., (2020), it is suggested that multimodal travel patterns also may influence individuals' perceptions and attitudinal reactions to different transport services, and people's perceived effectiveness of cycling initiatives may be different due to their use of other transport modes, such as public transport. Therefore, it would be helpful for future studies to consider this factor in their classification methods.

Finally, this paper considers differences among people's sociodemographic characteristics (subjective factors), and it does not include objective factors such as the built environment, accessibility to public transport, topography, and street connectivity. Further research is required to consider objective factors when assessing differences among people's perceptions of effectiveness.

Author contributions

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

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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