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The cover image is a photo of the 1966 flood of the Arno in Florence (Italy).

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Logistic models explaining the determinants of biking for commute and non-commute trips in Lahore, Pakistan

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Abstract
The determinants of biking behavior are less studied in a wide range of developing countries including South Asia. This study takes Lahore, Pakistan as a case-study city to explore the factors defining commute and non-commute bike trips as well as commuting by bike. These issues were analyzed by collecting data from 379 subjects accommodating in three socio-economic statuses (lower, medium, and higher) in Lahore in spring 2018. The data were analyzed by applying multinomial logistic regression for investigating biking frequency and binomial logistic regression for examining commuting by bike. The results show that gender, age, education, income, purpose of majority of trips, preferred distance to travel using cycle, preferred time to travel using cycle, and preferred bike trip purpose are significantly correlated with biking frequency. The significant determinants of bicycle commuting included categories of education, the purpose of the majority of trips, using bike in combination with other modes, preferred distance to bike, preferred biking time, and preferred bike trip purpose are associated with bicycle commuting. Commuting by bike is a more popular in socio-economically weaker neighborhoods. The discussion of this study shows that the determinants of biking in the sample in Lahore are different from those that have already been addressed by studies undertaken in high-income countries.

Keywords
Cycling; Active transportation; Sustainable mobility; Human perceptions; Pakistan.

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1 Introduction

The topic of biking determinants has widely been investigated across the highincome countries. In the recent past, the topic has also got the attention of the researchers from emerging economies and literature findings on the topic are also being surfaced from the developing world. However, the share of such studies in the overall volume is quite less. Also, the variation in the results of such limited studies is high as compared to the findings of the studies conducted in the developed world. This study focuses on exploring the biking determinants in Pakistan primarily to enrich our understanding of the dynamics associated with the biking in the context of a developing country and to find out the similarities and differences of the results in comparison with the literature findings relevant to the developed world.

As of many developing countries, there are not sufficient studies available for cycling in Pakistan. JICA's study included bicycle's trips stated that 45% trips counted for non-motorized in Lahore (JICA, 2012). This study included both pedestrian and cycling as non-motorized modes of transport and data were analyzed with respect to number of trips without stating their purpose. Such primary data is not available for the biking in Pakistan for commuting and non-commuting trips. This data gap provides a rationale to conduct study on this subject i.e. determinants and cycling use in Pakistani society.

The World Bank Technical paper on non-motorized Vehicles (NMVs) in Asian cities categorized bicycle, cycle rickshaw and carts as non-motorized vehicles. It concluded that NMVs were more efficient on shorter distance of travel while for larger distances, motorized transport modes were more efficient (Replogle & Mundial, 1992). But, the research findings on the aspect of short distance travelling with non-motorized seems inapplicable with the increase in travel distances in large cities such as Lahore, due to rapid urbanization and lack of infrastructure or safety measures for bicycle users in Pakistan. The value of time, speed and price of mode is also important factor for promoting the NMVs in Asian cities (ibid). This study revealed that choice of non-motorized mode is based on distance and cost of travelling. Bicycle's trips share is higher in urban places of Asian countries with low per capita income in comparison to Chinese and Indian cities, where the use of bicycles is declining due to non-availability of bicycle road infrastructure i.e. dedicated lanes (Tiwar et al., 2008). This study revealed that bicycle infrastructure and income level are the determinants of biking in Asian cities. Another study in the Indian city of New Delhi stated that most cycle users were male and belong to low income class (Arora 2013). Based on the findings, Arora (2013) also concluded about the effective role of gender as an important determinant of cycling in the Asian cities.

In other neighbouring country i.e. Bangladesh, research identified four factors of bicycle promotion in Sylhet city; those were health, convenience, weather and a deterrent factor of cycling due to more hazard as compared to motorized vehicles (Nawaz, 2015). However, studies on biking determinants within the context of Pakistan are very hard to find. The JICA study (2012) included biking as a mode of transport and provided trip count data only. In another study, (Aslam et al., 2018) looked into the potential of cycling in Lahore based on a descriptive analysis of the available opportunities and constraints. While looking into the relevant literature emerging from other neighbouring countries such as China, India and Bangladesh, various studies mainly identify biking infrastructure, weather, gender, travel distance and income level as determinants of biking. This research mainly focuses on investigating biking determinants in Pakistan.

The objective of this study is to find the correlates of biking frequency including commute and non-commute trips as well as the determinants of commuting by bike using the primary data collected in Lahore, Pakistan. It is also intended to descriptively show the differentiation of biking in different socio-economic levels in the city. A marginal task taken in this study is finding the differences between biking determinants in Lahore, compared to those of high-income societies mostly located in Europe, North America, and Australia.

The first section provides an overview of the topic and rationale behind conducting this study. It also highlights the main objective of the study. The second section offers a review of the literature and presents the results of the past studies on the topic of biking determinants. It also covers the methodological considerations of

similar past studies to report on the methodological consistencies and variations which leads to the methodology section of this study. The next section presents the study findings based on the inferential analyses which is followed up by the discussion section where the results of this study have been compared with the literature findings, particularly those emerging from the developed world. The last section concludes this study on the basis of findings and discussion.

1.1 Biking Determinants

The bicycle is a greener mode of transport and it needs to be promoted for better air quality management, health benefits and reduction of carbon emissions and also improve accessibility of the poor segment of community. In some countries, promoting bicycling is on the agenda of policy of the respective governments while in others effort at the individual level is the main cause of its promotion (Nawaz 2015). Policy makers are keen to identify the biking determinants while looking into the theory and available evidence to formulate policies for behavioural change to attract more cycle users (Chatterjee et al., 2013). In a comparative study of Germany and the USA, (Buehler, 2011) found that despite having been among the highest motorization rates in the world, Germans make about four times more share of trips by active transportation modes including cycling as compared to Americans. On investigating deeper, he concluded that the main determinant causing the difference in the person's mode choice behaviour is transport policy making the car travel slow, expensive and thus discouraging. Another study conducted by (Douglas, 2014) pooled the possible determinants like biking infrastructure, traffic safety, attitude by other mode users toward bicyclists, travel distance, income level, knowing how to cycle, health benefits and its integration with other modes of transport. The policy making cannot be effective unless it is derived from strong evidence of biking determinants. Such informed policy making can help in transforming the behaviour either through providing incentives or restricting any activity for bringing change in the society. (Caulfield et al., 2012) specifically investigated the determinants of biking infrastructure in Dublin and found that exclusive biking infrastructure segregated from motorized traffic is the leading preference of the cyclists.

In many studies, biking as a commuting mode has not been studied in isolation; rather it has been investigated as a part of overall transport system where bike sharing system is integrated with other modes of traffic to cover longer travel distances in large cities. In a similar such study conducted in Ningbo, China, (Guo et al., 2017) investigated the factors affecting bike-sharing usage and found gender, bike ownership, travel time, location of bike-sharing station, trip model and perception of bike-sharing as important determinants of bike use. Some researchers aimed at school-based commuting trips to identify the determinants of travel behaviour with respect to active travel modes including bike. (Irawan & Sumi, 2011) conducted such a study in Yogyakarta, Indonesia and found the travel distance from home to school is the main determinant of active travel mode choice. They also identify other significant determinants of age, gender and student's household characteristics. In a trans-national study, (Masoumi, 2019) investigated travel mode choices of the residents of Tehran, Istanbul and Cairo and identified the lack of biking infrastructure, socio-cultural issues exerting a pressure on biking and personal preferences as important determinants of biking. In another study conducted in Abu Dhabi, United Arab Emirates, (Badri et al., 2012) found gender, educational level of children, number of cars owned, nationality and number of children as important determinants of biking or walking decisions made by the parents for the children commuting to schools.

In South Asian region, there are some studies on biking promotion conducted within the Indian context. Tiwari et al. (2008) conducted a study in some Asian cities from Sri Lanka, India and China. They investigated about trends, potentials and association of biking with poverty and concluded that cycling is a transport mode of low-income people. They also shed light on the role of biking friendly policies of respective governments in each case and found out that most of cities' residents switched to motorized modes due to non-friendly government policies towards biking infrastructure. While in comparison, Chinese cities of Beijing and Shanghai observed 20 to 30% biking trips due to biking-friendly policies of governments; mainly a decent biking

infrastructure. (Majumdar & Mitra, 2015) conducted a study to identify factors affecting bicycling in small sized cities of India and found physical factors, safety concerns and topographic features as the main determinants of biking.

Reviewing the similar past studies on the topic, it has been found that a variety of approaches have been used to find out the determinants of the biking in urban settings. The topic has sufficiently been addressed within the developed countries context; however, it is still a matter of deeper inquiry for the developing world. There are lesser studies available which took the biking mode exclusively for investigation (Rietveld & Daniel,2004; Buehler,2012; Fuller & Winters, 2017; Aslam et al.,2018; de Geurs et al.,2019), while many studies explored the topic either through merging it in a wider group of active travel modes including walking (Yu, 2014) and public transit (Frank, 2004; Norwood et al., 2014; Mueller et al., 2015; Brown et al., 2016; Rojas-Rueda, 2019) or studied it in an overall sharing system (Park, Kang et al., 2014; Guo, Zhou et al., 2017; Hosford & Winters, 2018) where biking mode is integrated with other modes of traffic to facilitate riders to cover longer travel distances in large urban areas. Some researchers focused on educational based commuting trips and examined the travel behaviour of students (Irawan & Sumi, 2011; Badri et al., 2012) while others focused on job based commuting patterns (Panter et al., 2013). There are studies which also target the non-commuting trips through biking mode. The data collection method has mainly been the survey of the target population (de Souza et al., 2014; Fernández-Heredia et al., 2014), while some studies also relied on investigating the matter qualitatively through theoretical research (Koglin & Rye 2014), case study research (Zayed, 2016) or expert interviews; however such studies mainly focused on biking infrastructure (Caulfield et al., 2012). Inferential analyses, mainly the binomial and multinomial regression model analyses (Cole-Hunter et al., 2015; Muñoz et al., 2016) have been found the leading data analysis technique in the majority of the papers. Some papers also opted for discrete choice modelling (Masoumi, 2018; Masoumi, 2019) depending upon the objectives of their studies while some also employed simple descriptive analyses (Aslam et al., 2018) for presenting their results.

2. Methodology

The main questions that this manuscript seeks to answer are (1) which individual, household, and perceived factors determine biking frequency in Lahore? (2) which traits of different types define commuting by bike in the case city? In this study, it is hypothesized that the socio-economic, household, and individual factors as well as personal preferences and perceptions of biking are the most important determinants of biking in Lahore as an example of large cities in Pakistan. In the meantime, it is meant to prove that biking is a commute mode mainly for lower socio-economic statuses, namely for people accommodating in more deprived or more traditional neighbourhoods.

The data was collected in different districts of Lahore, Pakistan by interviewing people based on a standard questionnaire in spring 2018. The sample included 379 subjects accommodated in three different socio-economic statuses (lower, medium, and higher) accessing to traditional and older bazaars, uptown bazaars, and pedestrian malls (Fig.1).

The questionnaire consisted of 19 questions leading to development of 17 categorical/dummy variables, two open-ended variables, and two continuous variables targeting on socioeconomics, bike trip characteristics, biking barriers, and preferred travel specifications.

The descriptive findings of this exploratory survey were already published in detail in a previous publication of the authors i.e. (Aslam, Masoumi et al., 2018).

The two main dependent variables that are examined in this paper are biking frequency and commuting by bike. The former variable refers to the frequency of all bike trips for commute and non-commute purposes.

The question that was asked from interviewees was "what is the frequency of you cycling routine?" and the options were daily, weekly, monthly, occasionally, and need based.

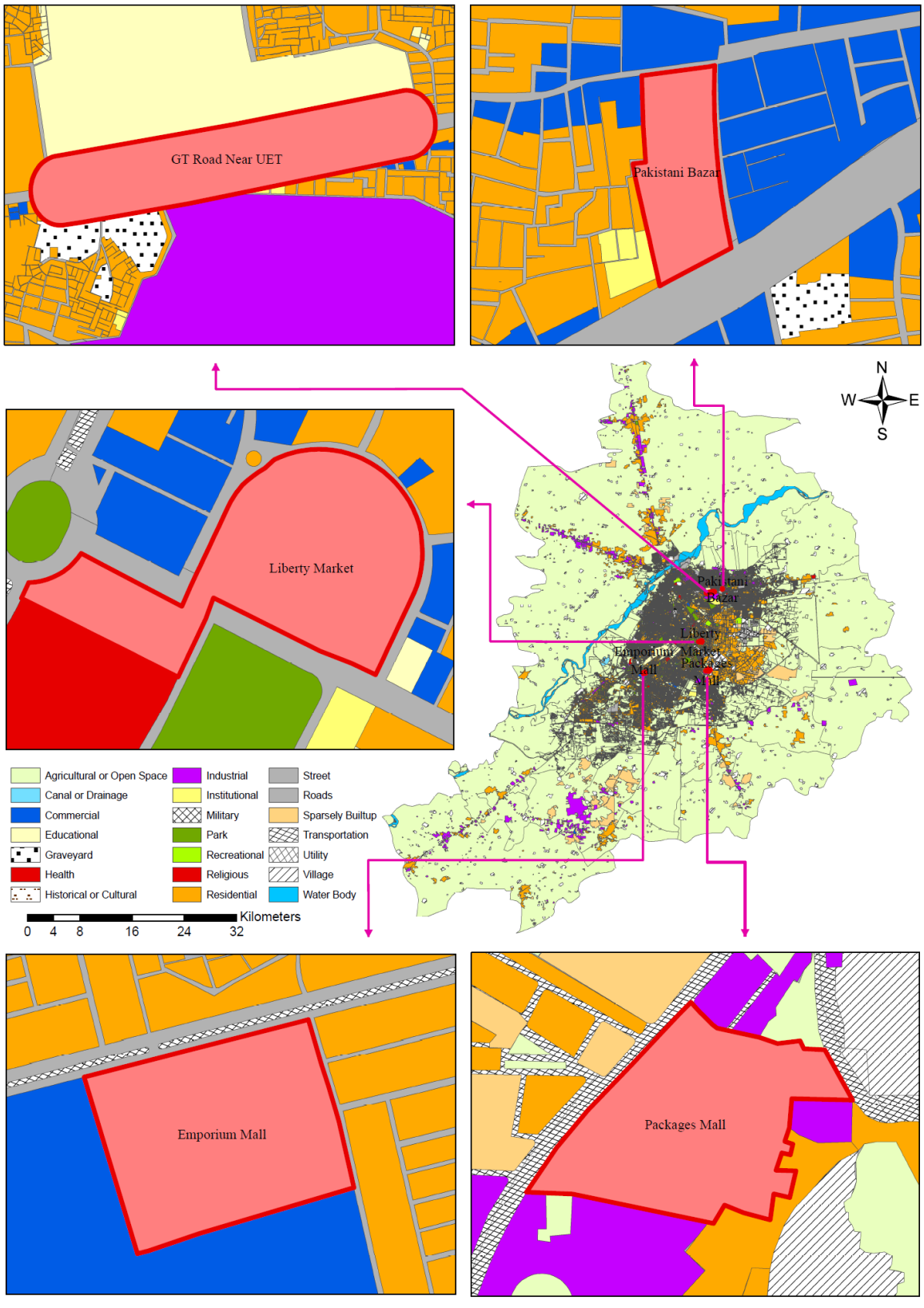

Fig.1 Location of case study districts in Lahore City (Source: Aslam et al., 2018)

The second variable was a binary one developed by the question "do you use cycle for commuting?" and two options of yes and no were given to the respondents.

In order to analyze the commute and non-commute biking frequency and biking as a commute mode in the sample, multinomial logistic regression (MNL) and binary logistic (BL) modelling were applied respectively. The MNL technique is generally explained by formula 1 and 2 respectively.

$$P = \frac{\exp(V_{in})}{\sum_{j=1}^{k} \exp(V_{jn})} \quad (1)$$

Whereas:
$P_n(i)$ is the probability that cycling has a frequency of i,
V_{jn} is the utility derived by individual n having frequency j,
K is the number of possible frequencies of cycling by the respondents.

For exploring the probability of commuting by bike the general formulation of binary logistic model is applied (Formula 2).

$$P = \frac{\exp(\alpha + \sum_{i=1}^{k} \beta_i x_i}{1 + \exp\ (\alpha + \sum_{i=1}^{k} \beta_i x_i)'} \quad (2)$$

Whereas:
P is the probability that respondents commute by cycle (commute by cycle=1),
x_i is each explanatory variable,
α is a constant term,
β_i is the regression coefficient of the model.

Thirteen explanatory variables were selected for both models: gender, age, income, education, know how to ride bicycle, no of cycle user in house, no of cycle owned in house, purpose of majority trips, use cycle in addition or split of other mode, preferred distance to travel using cycle, preferred time to travel using cycle, preferred bike trip purpose, and the most important aspect of biking. The MNL model (biking frequency), need-based biking was taken as the reference category, so the results were relevant to this option. For the purpose of interpretation of results, P-values less than 0.05 were taken as significant and values between 0.05 and 0.10 were accepted as marginally significant.

3. Findings

Tab.1 summarizes the frequencies of the responses including dependent and independent variables. The question regarding biking frequency was answered by 115 respondents, more than 31% of whom bike in a daily manner and 32% bike occasionally. More than 70% of the respondents have declared that they may use bike as a commuting method. Although biking is not a serious transportation mode choice in Pakistan according to the literature, but the descriptive findings show that it is used, more or less, for almost frequently (daily or weekly) especially for commuting.
Moreover, number of bikers in the household is a marginally significant variable (P=0.056). Interestingly, bike ownership, using bike combined with other modes, the most important motive behind cycling are not correlated with biking frequency. Whether they bike because of affordability, reliability, or accessibility is not associated with the number of their bike trips.
The results of the MNL model shows that eight variables of gender, age, education, income, purpose of majority of trips (not only biking), preferred distance to travel using cycle, preferred time to travel using cycle, and preferred bike trip purpose are significantly correlated with biking frequency (Tab.2).
The most significant explanatory variable is the dominant purpose of the majority of trips including recreation (16.5%), educational (27%), work (7%), health, fitness, and wellbeing (49.6%). This indicates that biking frequency is highly significantly related with who the person is and what his/her main daily overall travel

purpose is. Another highly significant variable is education. This variable consists of five educational levels: under matric (13.9%), matriculation (27.8%), undergraduate (28.7%), graduate (22.6%), and post-graduation (7%).

Variables	Category	n	Share of Sample	Variables	Category	n	Share of Sample
Cycling Frequency	Daily	36	31.3%	Purpose of majority Trips	Recreation	19	16.5%
	Weekly	21	18.3%		Education	31	27.0%
	Monthly	7	6.1%		Work	8	7.0%
	Occasionally	37	32.2%		Health, Fitness, Wellbeing	57	49.6%
	Need Based	14	12.2%	Use cycle in addition or split of other mode	Yes	92	80.0%
Gender	Male	99	86.1%		No	23	20.0%
	Female	16	13.9%	Preferred distance to travel using cycle	<1	4	3.5%
Age	15-24	46	40.0%		0.25 Km	28	24.3%
	25-54	69	60.0%		up to 5 Km	43	37.4%
Income	0-15000	29	25.2%		1-2	1	0.9%
	15000-50000	70	60.9%		5-10 Km	26	22.6%
	50,000 - 100,000	15	13.0%		10-15 Km	13	11.3%
	>100,000	1	0.9%	Preferred time to travel using cycle	under 15 min	64	55.7%
Education	Under matric	16	13.9%		15-30 Min	41	35.7%
	matriculation	32	27.8%		up to an hour	10	8.7%
	Under-graduate	33	28.7%	Preferred bike trip purpose	Recreation	18	15.7%
	Graduate	26	22.6%		Education	34	29.6%
	Post-graduation	8	7.0%		Shopping	4	3.5%
Know how to ride bicycle	Yes	115	100.0%		Work	52	45.2%
No. of cycle users in household	0	8	7.0%		Health, Fitness, Wellbeing	7	6.1%
	1	50	43.5%	Commuting by bike	Yes	84	70.5%
	2	29	25.2%		No	35	29.4%
	3	13	11.3%	Important motive behind cycling	Affordability	47	40.9%
	4	14	12.2%		Reliability	35	30.4%
	5	1	0.9%		Accessibility	33	28.7%
No. of cycles owned in household	0	9	7.8%	Valid		115	100.0%
	1	77	6.0%	Missing		264	
	2	25	21.7%	Total		379	
	3	1	0.9%				
	4	3	2.6%				

Tab.1 The frequencies of responses of dependent variables

Effect	-2 Log Likelihood of Reduced Model [a]	Chi-Square	df	P-Value
Gender	131.249	9.811	4	0.044
Age	131.451	10.013	4	0.040
Income	138.465	17.027	8	0.030
Education	157.044	35.606	16	0.003
Know how to ride bicycle	121.438	0	0	-
No of cycle users in household	152.365	30.927	20	0.056
No of cycles owned in household	135.722	14.284	16	0.578
Purpose of Majority Trips	162.333	40.895	12	<0.001
Use Cycle in addition or split of other mode	127.009	5.571	4	0.234
Preferred distance to travel using cycle	151.502	30.064	16	0.018
Preferred time to travel using cycle	139.196	17.758	8	0.023
Preferred bike trip purpose	153.189	31.751	16	0.011
Important Aspect behind cycling	127.063	5.625	8	0.689

The reference category is: Need-Based

Tab.2 Results of multinomial logistic regression for cycling frequency

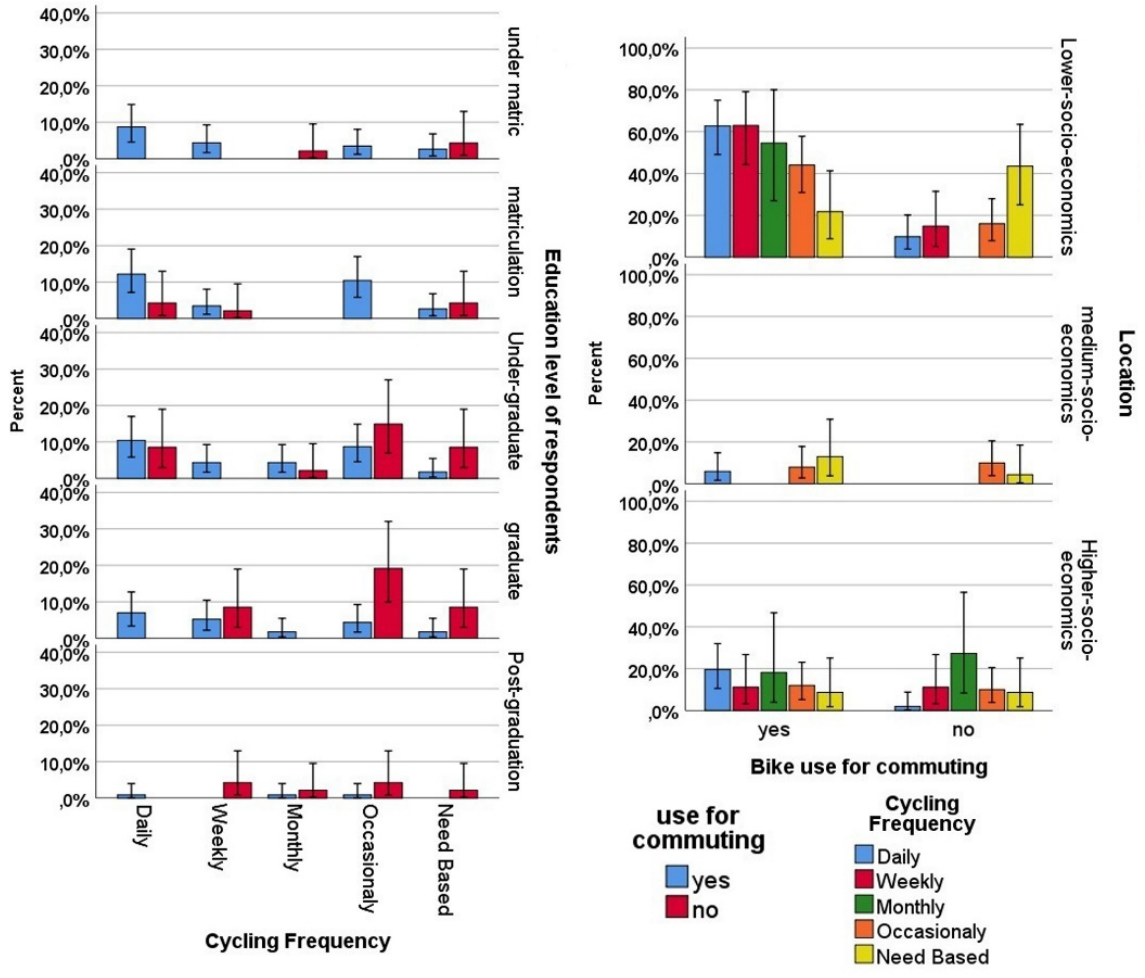

Fig.2 Left: Frequencies of bike commuting based on education level. Right: Cycling frequency in different socio-economic statuses in Lahore city

Fig.2 shows how cycling frequency varies by different education levels (right). Nevertheless, to have a more precise understanding of the direction of the significant variables, more information is needed about the coefficients.

Tab.3 provides this information about the significant categories (P<0.05) and marginally significant categories (0.05<P<0.10). According to these results, young people aged 15 to 24 years are more probable to bike daily instead of need-based compared to those respondents with 25-54 years of age.

	Cycling Frequency	B	Std. Error	Wald	df	P-Value
Daily	Age of Respondents=15-24	11.492	6.864	2.803	1	0.094
	Age of Respondents=25-54			Reference		
	No. of cycle users in household=1	75.686	31.639	5.723	1	0.017
	No. of cycle users in household=2	75.869	32.015	5.616	1	0.018
	No. of cycle users in household=3	69.639	31.340	4.937	1	0.026
	No. of cycle users in household=5			Reference		
	Purpose of Majority Trips=Education	7.595	4.039	3.535	1	0.060
	Purpose of Majority Trips=Health, Fitness, Wellbeing			Reference		
	Use cycle in addition or split of other modes=Yes	7.593	3.632	4.370	1	0.037
	Use cycle in addition or split of other modes=No			Reference		
Weekly	Age of Respondents=15-24	13.595	6.990	3.783	1	0.052
	Age of Respondents=25-54			Reference		
	No. of cycle users in household=1	73.141	31.654	5.339	1	0.021
	No. of cycle users in household=2	80.534	32.087	6.300	1	0.012
	No. of cycle users in household=3	70.450	31.385	5.039	1	0.025
	No. of cycle users in household=5			Reference		
	Preferred travel distance using cycle=up to 5Km	-13.947	6.971	4.003	1	0.045
	Preferred travel distance using cycle =1-2Km			Reference		
	Preferred bike trip purpose=Work	-12.338	6.268	3.875	1	0.049
	Preferred bike trip purpose= Health, Fitness, Wellbeing			Reference		
Occasion	Age of Respondents=15-24	12.529	6.864	3.332	1	0.068
	Age of Respondents=25-54			Reference		

Tab.3 Parameter Estimates for the MNL model (dependent variable: cycling frequency. Reference category: Need-Based)

Households with between 1 and 3 bike users are much more likely to bike daily relative to need-based compared to those household that have 5 bike users.

Respondents whose main travel activity is with the purpose of education are more probable to bike daily instead of need-based compared to those who cycle because of health, fitness, and wellbeing.

Perhaps these people are students who do not own or access a car or motorbike and do not use public transport, or those who cycle for health, fitness, and wellbeing usually bike whenever there is a need rather than continuously. As expected, those people who bike as a completion of other modes are more likely to do it daily rather than need-based compared to those who do not combine biking with other travel modes.

Like biking in a daily manner, it is more probable for people ages 15-24 to bike weekly instead of need-based compared to people ages 25-54. Moreover, households with fewer bike users are more likely to cycle weekly rather than need-based compared to those households that have 5 bike users.

The respondents who prefer to bicycle less than five Km are less likely to do it weekly instead of need-based compared to people who prefer to bike one to two Km. People whose main biking purpose is commuting are less probable to cycle weekly instead of need-based compared to people who bike for health, fitness, and wellbeing. Finally, respondents of this sample that were aged 15 to 24 years are more probable to bike occasionally instead of need-based compared to those respondents with 25-54 years of age.

Table 4 summarizes the model validity tests. The Pseudo R-Square results show very high amounts, i.e. the Nagelkerke value is 0.92, indicating that the model explains 92% of the variances. The Chi-square and the goodness-of-fit test also confirm the validity of the model.

	Model	**-2 Log Likelihood**	**Chi-Square**	**df**	**P-Value**
Model information	Null	368.784	-	-	-
	Final	121.438	247.346	140	<0.001
Goodness-of-Fit	Pearson	-	481.928	288	<0.001
	Deviance	-	120.052	288	1.000
Pseudo R-Square	Cox and Snell		Nagelkerke		McFadden
	0.884		0.920		0.668

Tab.4 Model Fitting Information of the binary logit model for commuting by bike

The results of the binomial logit model show that education, the purpose of the majority of trips (all modes), using bike in combination with other modes, preferred distance to bike, preferred biking time, and preferred bike trip purpose are the variables that are generally correlated with commuting by bike or at least one of their categories are associated with bike commuting (Tab.5).

Three categories in the education variable are significantly correlated with bike commuting, indicating that if people have studied up to under matric, matriculation, and undergraduate levels, then they are more likely not to commute by bike.

If the purpose of most trips is working, then people are less probable not to commute by bike, or in other words, they are more probable to commute by bike. Of course, this finding is logical and expectable. In very near commuting distances like 0.25 Km, it will be more likely not to bike.

The reason is probably that in such distances, people in Lahore prefer to walk rather than bike. Surprisingly, in short or middle commuting distances of less than 15 minutes and between 15 and 30 minutes, the respondents prefer not to cycle. Finally, for those who bike motivated by recreational purposes are less likely to commute to work.

The results of the model validity test are illustrated in Tab.6. The omnibus tests result indicated validity of the model (P=<0.001). the Nagelkerke R-square is more than 75%, indicating that 75% of the variation can be predicted by the model.

Category	B	P-Value	Exp(B)	Category	B	P-Value	Exp(B)
Gender=Male	-0.953	0.351	0.386	Preferred distance to travel using cycle	-	0.056	-
Age=15-24	-0.810	0.345	0.445	Preferred distance to travel using cycle=0.25 Km	8.789	0.014	6561.218
Income	-	0.637	-	Preferred Distance to travel using cycle=up to 5 Km	1.679	0.338	5.361
Income=0-15000 PKR	2.445	0.313	11.525				
Income=15000-50000 PKR	1.313	0.574	3.717	Preferred Distance to travel using cycle=5-10 Km	-0.631	0.707	0.532
Income=50000-100000 PKR	0.974	0.637	2.650	Preferred Distance to travel using cycle=10-15 Km	-20.131	1.000	≈0
Education	-	0.094	-	Preferred Distance to travel using cycle=more Than 15 Km	-0.906	0.587	0.404
Education=under matric	-4.395	0.024	0.012	Preferred Time to travel using cycle	-	0.131	-
Education=Matriculation	-4.532	0.021	0.011	Preferred Time to travel using cycle=under 15 minutes	5.528	0.073	251.605
Education=Undergraduate	-3.828	0.028	0.022	Preferred Time to travel using cycle=15-30 minutes	6.009	0.048	407.279
Education=Graduate	-1.628	0.284	0.196	Preferred bike trip purpose	-	0.192	-
No. of cycle user in household	-0.616	0.223	0.540	Preferred bike trip purpose=Recreation	-4.146	0.038	0.016
No. of cycle owned in household	-0.146	0.822	0.864	Preferred bike trip purpose=Education	-1.824	0.240	0.161
Purpose of majority trips	-	0.082	-	Preferred bike trip purpose=Shopping	1.413	0.595	4.108
Purpose of majority trips=Recreation	2.001	0.184	7.396	Preferred bike trip purpose=Work	-2.205	0.163	0.110
Purpose of majority trips=Education	0.079	0.947	1.082	Aspect driving using cycle	-	0.340	
Purpose of majority trips=Work	-5.225	0.037	0.005	Aspect driving using cycle=Affordability	1.125	0.331	3.081
Use cycle in addition or split of other mode=Yes	-3.120	0.002	0.044	Aspect driving using cycle=Reliability	1.643	0.144	5.170

Tab.5 Binomial logistic model for commuting by bike (Yes coded as 1, and No coded as 2)

	Category	Chi-square	df	P-Value
Omnibus Tests of Model Coefficients	Model	99.479	28	<0.001
	-2 Log likelihood	Cox & Snell R-Square		Nagelkerke R-Square
Model Summary	65.490	0.567		0.755

Tab.6 Binomial logit model validity test results

The above two models reveal some of the predictors of cycling frequency and bike commuting in Lahore city. Due to limitation of work force and time, urban form characteristics were not modeled in form of variables in this study. According to the literature, such factors including land use, density, street configuration and connectivity can be influential on biking behaviours. As mentioned in the methodology section, in this study, the urban forms were classified in three groups of lower, medium, and higher socio-economic statuses, based on the accessibilities to different types of bazaars and malls.

Fig.2 integrates commuting by bike in these three socio-economic statuses. This figure relates cycling frequency, bike commuting, socio-economic status, and education level.

As observed, those respondents who have undergraduate and graduate university degrees and bike occasionally, are less likely to commute by bike. On the other hand, if people commute by bike, they do it in a daily routine. This is seen among almost all education levels. Those who commute daily are very probable to live in lower socio-economic neighborhoods (Fig.2-right).

As the MNL and BL models showed, the number of cycle users per household was a significant or marginally significant variables for cycling frequency and commuting by cycle, while household bike ownership was not significant in either of the models.

Fig.3 depicts the relationship between the number of cycling household members and household bike ownership with biking frequency and bike commuting. The mean of the number of cycling household members is higher than the mean of cycles per household.

This might be justified by shared use of bikes by household members. This result indicates that bike ownership may not be treated as car ownership that indirectly indicates car use according to the literature.

The purpose of the majority of trips is a significant predictor of both biking frequency and commuting. The purpose of bike trips is significantly associated with bike commuting.

Fig.4 illustrates the breakdown of these purposes broken down on commuting by bike. As expected, the largest share of commuting is related to "work" purpose, be it for all the modes or only for biking.

The next important purpose is education that makes more than one-third of the commute trips. Interestingly, the largest percentage of bikers who do not commute by bike is related to people who cycle for health, fitness, and wellbeing, and in general for physical activity, sport, and entertainment (10%).

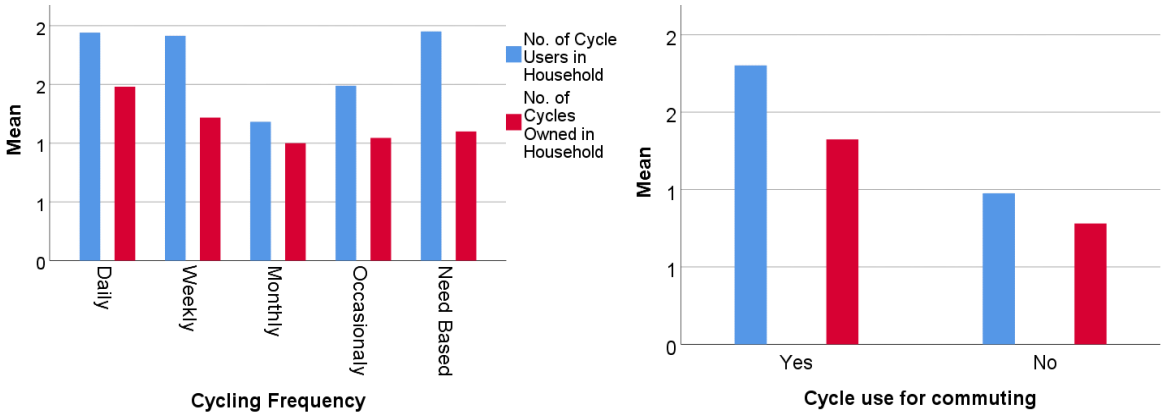

Fig.3 Breakdown of the means of household cycle users and bike ownership on cycling frequency and commuting by bike in the sample

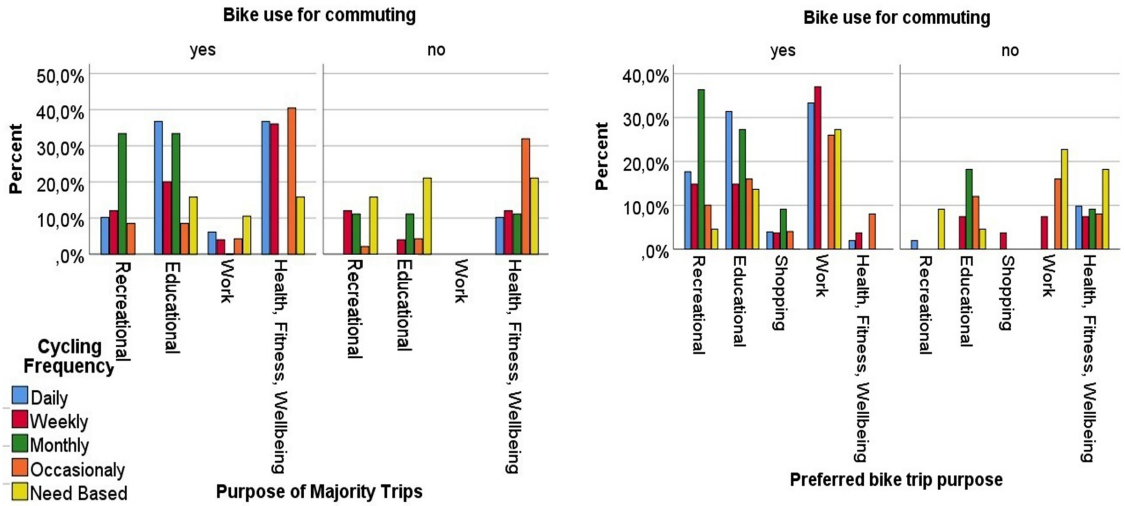

Fig.4 Purposes of all modes of travel and also bike trips based separated based on commuting by bike

4. Discussion

This section discusses the results with reference to latest work from other developed countries. The modelling of this study has been undertaken for producing correlations for the purpose of comparing the travel behaviors in Pakistan and South Asia with other contexts. However, it is also possible to use the results of the modelling for more applied purposes like transportation planning and policy making in South Asia or similar contexts like the Middle East and North Africa (MENA) or Asian countries. However, in an optimal case, the results of the models explaining the cycling frequency and commuting by cycle in Lahore can be generalized and transferred to other medium and large cities of South Asia region.

Applying the findings to other contexts will need strict and careful calibration before transferring. The reason is that the above two behaviours (frequency of general cycling and cycling to work) are heavily related to culture and climate, which may be very different in several regions compared to South Asia.

As mentioned above, the main interest of this study is to find contextual differences between biking behaviors in Pakistan and South Asia with other contexts.

Below some of these differences have been highlighted.

A quantitative study from China (Li & Zhao, 2015) shows that students who commute for education purposes and reside on the suburbs belong to different socio-economic backgrounds and prefer to cycle within 3 km of distance from their home to school whilst in Lahore people did not want to travel through bicycle for shorter distances. The reason is education and population policy designed by the country which is not given a due attention in case of Lahore. One step ahead of that, bicycle friendly cities (e.g. Ireland) are introducing and improving bicycle sharing schemes which is getting popular among people especially in higher-income groups and due to the increasing awareness among drivers (Murphy & Usher, 2015) but are not significantly considered in case of Lahore.

A study from America shows that different institutions at national level come across to take into account of people's choices to travel through healthier, safer and low-carbon travel modes such as walking and biking, and define policies for neighbourhood by encouraging them adopt through the provision of necessary facilities and infrastructure (Abel et al., 2019). Similar is the case with other high income countries such as Britain, European countries and Australia (Docker & Johnson, 2018; Cervero et al., 2019).

This shows a gap between residents of Lahore who are willing to bicycle if are given enough opportunities and biking friendly infrastructure and the policy makers and implementers at national/subnational level in Pakistan.

Results showed that people who have obtained education up to matriculation used bicycle either on daily basis or occasionally and similar was the case with undergraduate students too, whilst it is already established that frequency of bicycling reduces with the increasing levels of education, especially, in the context of commuting (da Silva Bandeira et al., 2017).

In Lahore, lower socio-economic groups frequently commute on daily or weekly basis whilst the trend is not considerable in medium and higher socio-economic groups. This shows that the difference in socio-economic characteristics of a community effects the choice and frequency of bicycling to commute. In contrast, trends towards cycling in all three socio-economic groups towards bicycling have been closed in developed countries such as Sweden (Bastian & Börjesson, 2018) and all socio-economic groups are inclined to bicycle.

This paper contributes that there seems a strong inter-related effect of education, socio-economic characteristics and the need of commuting to cycle (based on the distance between residence and workplace) which previously has not been explored significantly in case of Lahore and can be achieved even with very limited available data on socio-economic conditions of Lahore as presented by (Jain & Tiwari, 2019).

Results showed that considerable number of people of Lahore bicycled for health, fitness and wellbeing purposes following educational purposes whilst the least number of users cycled for sake of work purpose. Also, participants from Lahore showed different preferences that they would like to cycle more for work trips

compared to recreational trips and as is happening in other high-income and well developed countries such as Australia (Heesch et al., 2015).

However, it is yet to be investigated that what could be the possible factors that may influence people's preferences to bike for a specific purpose-oriented trip and how bicycling could be promoted for various trips. Biking to work may add additional advantage of health and wellbeing as is also practiced in countries like Singapore (Raustorp & Koglin, 2019).

There seem other factors linked with this situation, for example, distance to travel or/and time constraints and other health issues. For example, as if health and wellbeing policies are implemented at national/subnational levels then at least in public sectors biking to work can be encouraged with the provision of necessary facilities and required support as done in South-Western Norway (Jahre et al., 2019) and can be further extended to private sectors.

In countries such as China, bicycling is well integrated mode with other public transit modes which allow travelers to use partial modes of travel as per their own convenience (Zhao & Li, 2017). A similar bicycle-bus integrated system may support bicycling more in Lahore. In this study, around 80% of participants were willing to use bicycle in split or addition to other modes of traffic which is already an ongoing practice in developed countries and a well-accepted solution to urban traffic problems (Frade & Ribeiro, 2014).

Results also showed that people want to travel to work using bicycle and this might help them in saving costs of commuting. Therefore, it is need of the hour to take up willingness of people of Lahore towards cycling and design policies accordingly at least for smaller travel distances (say up to 5 km).

Even bike sharing policies as practiced in many countries based on various travelling activities could be good starting point (Midgley, 2009; Vogel et al., 2011).

Results showed that more than half of people of Lahore preferred to travel for shorter time span (less than 15 min) compared to longer travel time spans for which the possible reasons need to be well explained.

For example, in a detailed study from China, structural modelling equation is used to investigate the various factors effecting the shared use of bicycle, it was found that those bicycle users who travel for shorter distances are influenced by the effect of perceived behavioural control and certain habits especially on shared bicycle whilst in contrast to that for long distance users the prominent factors are subjective norms and attitudes (and behavioural intentions) (Xin et al., 2019).

In a contemplation based study from Australia, it is found that the closer proximity of residential area in relation to shared bicycle stations (or availability of bicycling) and destined places of trips may not are of any significance which is another indication that there might be other factors involved in deciding the travel time through bicycling (Heinen et al., 2018). However, in the same study it is also indicated that other factors may be are more supportive of bicycling by sharing bicycle friendly schemes (Haider et al., 2018).

Results showed that people of Lahore were willing to commute by bicycle, if like other countries such as China, government supports such policies and give subsidies and facilities on bicycle sharing schemes then it might facilitate people who are already willing to commute by bicycling (Cai et al., 2019). Such schemes can facilitate other aspects of urban mobility e.g. low carbon solutions through bicycling rather than motorization whilst making bicycle as more user-friendly and environmental-friendly mode (Aladin et al., 2019).

Results showed that affordability could be the main motivation behind bicycling compared to reliability and accessibility for the people of Lahore.

This is a clear indication and as discussed above as well that if people of Lahore are given opportunities and facilities by the government (or private sector) where they can cut the cost of travelling, they would certainly go for bicycling rather than spending on other modes of transport e.g. preference of cycles over cars (Pirlone & Candia, 2015). In addition, reliability and accessibility were also given weightage by the people of Lahore. This means that there are multiple-determinants that might target various groups of people with different needs, priorities and incentives (Majumdar et al., 2015).

There is not a single factor responsible to persuade people to bicycle or commute for any (specific) purpose (Cervero et al., 2019). There is involvement of complexity due to many factors involved in knowing the needs of people who can potentially bicycle whilst declining other modes of travel.

From the discussion so far, it is quite clear that people of Lahore are willing to (commute through) bicycle (solely or in split with other modes of transport) if are given suitable incentives and facilities as in other high income and developed countries. There are many governing factors that influence the choice of mode to travel particularly bicycle as studied by (Masoumi, 2013) that the sustainable modes like walking and bicycling are promoted when facilities/amenities are accessible.

It is required that a detailed study that involves multiple factors and determinants such as land use densities, people's preferences, incentives offered by government etc. should be carried out along with more advanced data collection and analysis methods.

Like all other studies, this study too has some limitations such as there is need to get more data (bigger sample size) and (complex analysis method to do) core analysis in the context of versatile relationships of time, travel distances and purpose of trip, health and publics' willingness and prevailing constraints (such as infrastructure).

5. Conclusion

This study analyzed the commute and non-commute biking frequency and also biking as commute mode in the sample using multinomial regression and binary logistic model. In this regard, thirteen explanatory variables used for both models i.e. gender, income, education, know how to ride bicycle, no. of cycle user in house, no. of cycle owned in house, purpose of majority of trips, use of bicycle in addition or split of other mode, preferred distance to travel using cycle, preferred time to travel using cycle, preferred bike trip purpose and important aspect of biking.

The result of analysis identified important biking determinants i.e. age, education level, purpose of trip and income level. While factors like bike ownership is not important as less bike ownership in house still has more bike user. People are willing to use bike in combination with other mode.

Surprisingly, people those bikes for health and well-being do not use bike for commuting whereas mostly people prefer to bike for shorter distance (15 min or less).

The study has identified that there is willingness to bike for shorter distance and also in connection with other modes e.g. bus or metro train etc. There is potential to promote biking as greener mode of transport if it is part of transport policies at provincial and local level.

This study identified determinants of biking i.e. age, education, income, purpose of trip, length of trip using bike, no. of bicycle users and no. of bicycle owned with respect to urban forms and socio-economic groups. Due to limitations, factors like land use, density, street configuration and connectivity could not be analysed and these factors can greatly influence biking pattern.

There is need to conduct studies on factors i.e. land use, density, street configuration and connectivity in connection with this study. This subject of bicycle remained ignored from researchers' side and from government in transport policy formulation in Pakistan too. More studies should be conducted in other cities of Pakistan with bigger data set using more factors to guide the policy makers for promoting biking in big cities of Pakistan.

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