How do the perceptions of neighborhood conditions impact active transportation? A study in Rajshahi, Bangladesh.

Shaila Jamal[a], Hossain Mohiuddin[b], Antonio Paez[a]

[a] *School of Earth, Environment and Society, 1280 Main Street West, Hamilton, Ontario, Canada, L8S4K1*

[b] *Institute of Transportation Studies, University of California, Davis, 1605 Tilia St, Ste 100, Davis, California*

Abstract

This paper aims to investigate the perceptions of neighborhood conditions and their effect on urban active transportation (UAT) in the context of a city in the Global South. We analyze data from a survey of commuters in the city of Rajshahi, Bangladesh. Concretely, we are interested in cycling and walking. A probabilistic model of mode use is estimated using disaggregate data collected in Rajshahi through a face-to-face survey in 2017. The study reveals that, similar to other regions in the world, students are more likely to use active transportation compared to other socio-demographic groups, and that motorized vehicle ownership is associated with lower probabilities of active transportation. Furthermore, the probabilities of choosing active modes at different neighborhood-level conditions were calculated based on the derived model for both students and non-students by residential and non-residential land-use type. In addition to the duration of the trip, the perceived neighborhood-level characteristics are critical for active transportation. Improving neighborhood conditions and their perception by the public can enhance the attractiveness of active travel, more specifically cycling for longer commutes. Based on the study findings, the paper

Email addresses: jamals16@mcmaster.ca (Shaila Jamal), hossain.mohiuddin19@gmail.com (Hossain Mohiuddin), paezha@mcmaster.ca (Antonio Paez)

discusses strategies to promote the use of active transportation in the context of a country in the Global South.

Keywords: Cycling; walking; perceptions; safety; crime; Global South; South Asia.

1. Introduction

Urban transportation in the Global South presents challenges that are often distinct from those in the developed world (Gwilliam 2003, 2013; Cervero 2013). Although rates of motorization do not significantly differ at similar levels of income, lower incomes in the Global South make auto ownership unaffordable for large segments of the population. This means that, unlike many places in the developed world, so-called alternative modes of transportation are in fact, quite the norm (Godefrooij and Schepel 2010). A case in point is Asia, where non-motorized modes of travel such as cycling, walking, rickshaws, and carts play a vital role in urban transportation. As is the case in the rest of the world, these modes of transportation offer affordable and environmentally-friendly mobility options.

Despite the widespread use of non-motorized modes, there is an upward trend in motorization in the Global South (Li 2011; Cervero 2014; Korzhenevych and Jain 2018). While, on the one hand, higher modality (i.e., the availability of a high number of different modes of transportation) is seen as a desirable policy goal (e.g., Grosse et al. 2018; Krueger, Vij, and Rashidi 2018; Nobis 2007; Vij, Carrel, and Walker 2013), as well as essential for more robust transportation polycultures (Miller 2011). The available evidence suggests that reliance on the car markedly reduces the set of other transportation alternatives (Lavery, Paez, and Kanaroglou 2013). Consequently, motorization can rapidly threaten higher modality and have other deleterious effects such as premature congestion, deteriorating environments that negate the health benefits of active travel, loss of street space for non-motorized travel, loss of safety, and changes in urban form that lock development in a trajectory that favors motorized travel (Gwilliam 2003; Tainio et al. 2016; Pojani and Stead 2015).

In this context, transportation planning in the Global South faces the challenge of scarcity in empirical evidence regarding the effectiveness of planning interventions (Zhao and Li 2016). This is particularly true in the case of urban active transportation (UAT), a form of mobility that is often ignored in planning and investment due to a lack of understanding of the benefits of non-motorized travel, including health benefits, reductions in congestion, less air pollution, fewer accidents, and fewer resources sunk in vehicle acquisition and maintenance (Rahul and Verma 2013). Thus, while many cities in the developed world have recognized the multiple benefits of active transportation and have devoted efforts to promote it (e.g., Carroll, Caulfield, and Ahern 2019; Martin, Goryakin, and Suhrcke 2014; Nazelle et al. 2011; Moniruzzaman, Paez, and Morency 2014), this form of mobility has not received nearly as much attention in policy and planning in the developing world (Cervero 2013; Hatamzadeh, Habibian, and Khodaii 2017). For these reasons, there is an urgent need to develop a better understanding of the factors that correlate with active transportation in regions in the Global South. Part of the challenge in the Global South is limitations on data availability. For example, attributes of the built environment are not collected in a systematic way by relevant authorities; events such as accidents may not be reported by the public due to low trust on the authorities; or data are zealously guarded by the authorities to limit accountability. Fortunately, directly asking people about their perceptions is now a well-established practice in many fields, including transportation research (see Van Acker, Van Wee, and Witlox 2010; Van Acker, Mokhtarian, and Witlox 2011). Furthermore, a wealth of research shows that behavior is influenced by those perceptions. This includes research on active travel both in the Global South and in developed economies (see, Gatersleben and Appleton (2007); Cleland, Timperio, and Crawford (2008); Akar and Clifton (2009); Liao et al. (2015); and Loo et al. (2015)).

With the above considerations in mind, this paper aims to investigate the effect of perceptions of the neighborhood on urban active transportation in the context of the city of Rajshahi, Bangladesh. Disaggregated data from a face-to-face survey are used to develop a probabilistic model of mode use. More concretely, the focus of the analysis is on cycling and walking, and how the use of these modes is affected by the attributes of the trip, the attributes of the individual, and individual perceptions of the social and physical conditions in the neighborhood. Perceptions of the social environment are particularly germane, since they are influenced by concerns about crime and safety that are all too common in many regions in the Global South (e.g., Landman 2012; Lemanski 2012; Zaluar 2012). In line with previous research in other regions, the results show that students are more likely to use active transportation than other socio-demographic groups, and that motorized vehicle ownership is associated with lower probabilities of using active transportation. The perceived UAT related characteristics of neighborhoods are shown to be particularly influential for the use of these modes. Improving neighborhood conditions and their perception by the public can enhance the attractiveness of active travel for longer commutes. Based on the study findings, the paper discusses strategies to promote the use of active transportation in the context of cities in the Global South with the similar socio-cultural background.

The data used in this research are not publicly available due to the data use agreement. In order to support as much openness as possible (see Brunsdon and Comber 2020), the code describing the data preprocessing as well as the model files needed to reproduce the results are publicly available[1].

2. Background

Compared to the developed world, limited evidences are available that focus on the correlates of the modes used for transportation in developing countries, particularly concerning UAT. Based on previous research, a number of correlates of mode use are known that are similar to studies in the developed world. This includes individual characteristics - such as age, gender, income, and education level - which have been found to affect the use of various modes of transportation in the Global South. However, because of the difference in socio-cultural and geographical contexts, some differences have been noticed in the direction and magnitude of effects (Larrañaga et al. 2016). For example, in a study of different working groups, Hatamzadeh, Habibian, and Khodaii (2017) found that women in Rasht, Iran are more likely to walk for commuting than men. This result is different from the findings in developed countries, where several studies found that compared to women, men are more likely to use active modes of travel (Buehler et al. 2011; Pucher et al. 2011; Laverty et al. 2013). In Brazil, studies found that the use of UAT decreases with age (Larrañaga et al. 2016; T. H. Sá et al. 2016). In contrast, examples are available in developed countries where older people are found to walk more compared to other age groups (Martín and Páez 2019; Laverty et al. 2013; T. H. de Sá et al. 2016). Also, in Brazil, studies have found that active travel decreases with increase in income and education levels (T. H. de Sá et al. 2016; Larrañaga et al. 2016; Silva Bandeira et al. 2017). Liao et al. (2015), in a study in Taiwan, found that walking and cycling are less popular among employed adults. Similar results have been found in India,

[1] See https://github.com/paezha/Neighborhood-Perceptions-and-Active-Travel-in-Bangladesh

where employed adults from high income households are more likely to use a car (Srinivasan, Pradhan, and Naidu 2007). In the case of the developed world, both similar (Ye and Titheridge 2017; Adams 2010; Cerin, Leslie, and Owen 2009) and opposite (Mackenbach et al. 2016; Munter et al. 2012) examples for income and education level's impact on UAT are available.

Findings by Aslam et al. (2018) in Lahore, Pakistan, are similar to those of developing countries. The study found that the use of bicycles decreases with age, income, and education level. The study also mentioned the cultural obstacles females face in using bicycles, a factor also discussed previously by Kuranami and Winston (1994). Among Asian countries, compared to China and Vietnam, females are less likely to use a bicycle in the Indian subcontinent (i.e. Bangladesh, India, and Pakistan) because of the traditional clothing style, patriarchal views, and cultural norms (Kuranami and Winston 1994; Aslam et al. 2018). Also, in predominantly Muslim countries such as Bangladesh and Pakistan, *purdah* (the social seclusion of women) makes it difficult for women to share crowded streets (Kuranami and Winston 1994), and therefore they make fewer trips compared to men and often use rickshaw (i.e. a two-wheeled hooded vehicle mostly used in Asian countries). Furthermore, in these countries car ownership is very low. In Bangladesh, where bicycles are mostly owned by low and middle-income individuals (which form the bulk of the population), poorer and less educated individuals use it daily and affluent and well-educated individuals use them occasionally (Kuranami and Winston 1994). In South Asian countries, bicycles are perceived as a means of transportation for people with low incomes. Interestingly, wealthier individuals in the USA are much more likely to own a bicycle (Poushter 2015).

In terms of trip attributes, Adlakha et al. (2018) and Srinivasan, Pradhan, and Naidu (2007) revealed that shorter trips correlate more strongly with active commuting in Chennai, India. Similar results have been found in Iran, where employed adults who prefer to walk for commute usually walk 800-1200 meters to work (Hatamzadeh, Habibian, and Khodaii 2017). In Pakistan, bicycle use is more preferred for commute when trip durations are less than 15 minutes and/or the type of work requires repeated trip making (Aslam et al. 2018). Recent studies have offered new insights about the use of UAT and objective measures built-environment in Latin American contexts. In Chile, Oliva, Galilea, and Hurtubia (2018) found that land-use such as residential and workplace density as well as the length of biking lane increases the likelihood of bicycle commuting. Rossetti, Saud, and Hurtubia (2019) also recommends that the existence of cycling infrastructure is necessary to ensure the safety of bicyclists. The study by Guzman, Arellana, and Alvarez (2020) in Bogota, Columbia suggests that increasing parking charges at workplaces could be an effective strategy to promote AT commuting. In Brazil, Larrañaga et al. (2016) found that increase in population density in the neighborhood increases the number of walking trips made by the individuals.

Modal shift can occur if factors that enable the shift are provided or the perceptions related to a specific mode is changed. For example, if there is a positive correlation between the presence of infrastructure in the neighborhood and walking (e.g., sidewalks, see Moniruzzaman and Paez 2012, 2016), then modal shift towards walking can happen if appropriate infrastructure is provided. According to the theory of planned behavior (Ajzen 1985), an individual's perceptions and attitudes can influence their behavior. The more positive feelings they possess, the higher the intention becomes and thus, they are more likely to perform the activity. Studies have found correlations between UAT use and perceived neighborhood characteristics. An example is the study by Giles-Corti and Donovan (2002) in Perth, Australia, where they found that an individual is more likely to walk if they perceive that sidewalks and shops are accessible and within a short distance. Individual perception of safety and security while traveling can also influence walking behavior. The same study (Giles-Corti and Donovan 2002) also reported that individuals are more likely to walk if they perceive their neighborhood as safe, attractive, and supportive of walking. In Belgium, it has been found that individuals' who perceive the accessibility to regular destinations as 'good' are more likely to use a bicycle (Van Cauwenberg, Clarys, et al. 2012). The same study also found that among women, increase in perceived safety from crime increases the probability of cycling. A qualitative study in Belgium concluded that increase in perceived traffic safety influences walking for transportation among men and women (Van Cauwenberg, Van Holle, et al. 2012).

On the other hand, in the developing countries of Global South, results from the studies on the impact of perceptions towards neighborhood characteristics on UAT behavior are mixed and complex (Oyeyemi et al. 2012; Adlakha et al. 2018). Possible reasons could be the difference in cultural contexts and socio-economic conditions (Oyeyemi et al. 2012), in addition to differences in the environment (Cervero 2013; Adlakha et al. 2018). Cultural norms as well as social practices in the South Asian countries are quite different from those of the South American countries. Also, the study by Larranaga et al. (2019) in Brazil suggests that different user groups can perceive different environmental characteristics differently and choose different environmental characteristics that they think will influence their probability of walking. In general, literature shows that important factors in the Global South's contexts are social conditions such as perceived levels of crime and traffic safety, and their relationship with active travel for recreation, leisure and/or transportation. Jia, Usagawa, and Fu (2014) conducted a study in Shanghai, China and found a positive correlation between perceived traffic safety and walking. Oyeyemi et al. (2012) and Gómez et al. (2010) also found that higher level of perceived safety from traffic influences more walking. The studies were conducted in Maiduguri, Nigeria, and Bogota, Colombia, respectively, which have higher rates of traffic accidents. A positive correlation between feeling safe from crime and walking has been found in Nigeria (Oyeyemi et al. 2012) and Curitiba, Brazil (Parra et al. 2011). Jia, Usagawa, and Fu (2014), on the other hand, found no association between perceived safety from crime and walking in Shanghai. The reason mentioned in the study (Jia, Usagawa, and Fu 2014) is that in general, Shanghai is perceived to be safe; thus, walkability and safety from traffic are more influential to walking than crime. In India, Adlakha et al. (2018) found negative association between active commuting and perceived safety from crime, whereas a study in Pakistan Gul, Sultan, and Jokhio (2018) found neutral impact between these two factors. In contrast, studies conducted in Brazil and Columbia suggested that perception of safety from crime and traffic, and the feeling of being safe while walking and cycling in the neighborhood, increase the likelihood of walking and cycling (Weber Corseuil et al. 2012; Hallal et al. 2010; Arellana, Saltarin, Larranaga, Alvarez, et al. 2020; Gutirrez et al. 2020). Studies are also available in Brazilian contexts where researchers found that the probability of walking and cycling (for leisure) is not significantly associated with traffic conditions as well as with safety related to walking and cycling (Gómez et al. 2010; Gomes et al. 2011).

Additionally, perception of the physical environment in the neighborhood is an important factor that influences the use of different modes of transportation. However, compared to developed countries, studies that explored these relationships in developing country contexts is limited. Arellana, Saltarin, Larranaga, Gonzlez, et al. (2020) reported that although primary/ main roads are not perceived as safe considering the high rates of traffic accidents, cyclists seem to prefer them more for easy connectivity even when there is no cycling infrastructure. However, presence of a cycling infrastructure does not mean that cyclist are safe from traffic accidents - it might reduce the likelihood, but cyclists won't be completely safe from road accidents (Huertas et al. 2020). Jia, Usagawa, and Fu (2014) and Cerin et al. (2014) found that higher levels of perceived accessibility to services in the neighborhood positively impact walking for recreation and transportation. Similar results have been found by Parra et al. (2011) where higher levels of physical activities (e.g. walking for leisure) was highly correlated with higher perceptions of neighborhood-level accessibility and higher perceptions of pedestrian facilities and pedestrian safety in the neighborhood. Perceived good connectivity of streets is positively related to walking and cycling among the Taiwanese employed adults (Liao et al. 2015). In Ghana, Acheampong (2017) found that higher level of perceived ease of cycling influences cycling to work.

The mixed findings from the developing countries indicate the need for addressing the idiosyncrasies of context while conducting active transportation studies in the Global South. Srinivasan, Pradhan, and Naidu (2007) and Larrañaga et al. (2016) also mentioned the need for developing an understanding of the context-specific features of mode choice as mode choice decisions substantially differ between the developed world and the Global South due to the differences in the level of vehicle ownership, travel needs and preferences, activity characteristics, and attitudes. Also, there are differences in socio-cultural contexts among the cities in the Global South. For these reasons, Adlakha et al. (2018) emphasized that researchers should be careful while translating findings across countries and/or cities. Compared to developed countries, fewer active travel related studies have been conducted in developing countries. Since evidence is still rare on active commuting in the Global South in general, and in South Asian countries in particular, this paper aims to better understand the factors that influence the use of different modes for commuting, focusing on UAT modes. Factors considered in this study are socio-demographic factors, trip attributes and most importantly, perceived environmental correlates, that is individual's perceptions towards the neighborhood's physical conditions such as walkability and cycling and social situations such as crime and safety discussed next.

3. Context and data

3.1. Geographical and policy context

Bangladesh is a South Asian country of about 160 million people experiencing rapid economic development and urbanization. Consequently, many cities in the country have experienced an adverse impact on their urban transportation systems, mostly traffic congestion, air pollution, and demand that exceeds the capacity of existing transport infrastructure. As a remedy to this situation, numerous transportation infrastructure development projects have been initiated in Bangladesh in recent years; however, few focused on UAT. Growth in urbanization with a focus on motorized vehicle infrastructure development usually influences lower rates of active travel, physical activity, and sedentary lifestyles, which is evident in the small and medium sized cities of the neighboring country, India (Adlakha, Hipp, and Brownson 2016b, 2016a).

The promotion of active means of travel could be a key strategy for tackling poor health outcomes, air pollution, reducing congestion and increasing traffic safety. Also, cycling and walking are affordable options for the general population in the Global South, indicating the need for safe and high-quality conditions to support these modes (Cervero 2013). Very recently, Bangladesh expressed a vision for improving the sustainability of its transport sector. The government has developed an Integrated Multimodal Transport Policy which suggests several initiatives in favor of public transport and UAT (Government of Bangladesh

2013), including a 'Pedestrian First' program, allocating more times and giving priority to pedestrians at traffic signals, widening footpaths, ensuring short walking distances to shops and services in non-urban areas, providing separate bicycle lanes in urban areas, and promoting road safety measures.

The study area, Rajshahi Municipality, is located in the north-west of Bangladesh. It is one of the earliest municipalities in Bangladesh, having been established in 1876. It is the fourth largest municipality of the country, with a total land area of 48.06 square kilometers and a total population of 0.45 million (Bangladesh Bureau of Statistics 2013). The population density is 9,359 per square kilometers (Bangladesh Bureau of Statistics 2013). Famed for its six big educational institutions, including universities and medical schools, Rajshahi is known as the "Education City" of Bangladesh. The city is well connected to the rest of the country by air, water and road; however, the residents depend entirely on road transportation for intra-city travel. The municipality has 571 kilometers of road in total (Bangladesh Bureau of Statistics 2013). Although several modes of transport are used for daily travel, less than 1% of households own private cars (Haque 2014), and only about 8% have motorcycles (Mitra 2016). Non-motorized modes such as rickshaw, van, pushcarts are more prevalent in the city as they provide door-to-door services. In other cities in the country, such as the capital city Dhaka, the use of bicycles for commuting is relatively rare because of associations in the popular imagery with low social status (Kuranami and Winston 1994). The opposite is observed in Rajshahi, where fifty-seven percent of households own bicycles, indicating residents' preference towards active modes of travel (Mitra 2016).

Rajshahi was once one of the world's most polluted cities. Continuous efforts by the city's authorities since 2004 changed this situation to the point where, in 2016, it became the top city in the world for decreasing air pollution

(62% decrease in PM10) (Khan 2017). This was the outcome of initiatives such as extensive tree plantation, reducing industrial pollution, and tackling transportation issues. Among the suite of initiatives to reduce air pollution, recently, the city took several measures to promote UAT. So far, 15 kilometers of pedestrian facilities have been built, and the expectation is to expand this to 48 kilometers (Hammadi 2016). To promote cycling, the city has also started building 10 kilometers of separate bicycle lanes, the first facility of this kind in Bangladesh (Hammadi 2016).

In recent years, cycling has been trending in Rajshahi compared to other cities in Bangladesh. With numerous educational institutes based in the city, many students from different parts of the city travel everyday for study. As in other places, students appear to be the most active in cycling (Whalen, Páez, and Carrasco 2013). Moreover, many young people-led cycling groups have been formed around the country, including Rajshahi, encouraging people to use bicycles regularly for commute and recreation. It has been chosen as the study area so that a reasonable number of UAT users can be surveyed to explore the influencing factors. Developing an understanding of the influencing factors of UAT will be crucial to promote UAT in the city. The results also contribute to build a more extensive knowledge base about UAT in the Global South.

3.2. Survey and data

A questionnaire was designed to collect residents' travel patterns and their perceptions of UAT conditions in their neighborhood. Several UAT studies (e.g. Dill and Voros 2007; Public Health Agency of Canada 2011; Peterborough City and County 2014; Auckland Transport 2016) were reviewed to inform the development of the questionnaire, which was also adapted to make it appropriate for the local context. The target population of the survey was residents of the study area.

The questionnaire asked respondents about their socio-demographic profile such as age, gender, occupation, income, and the number of household members. Respondents were also asked about the number of bicycles and motorized vehicles in their household. To determine their preference and level of use of UAT modes, the questionnaire also collected information on their daily walking and cycling in minutes. Regarding travel behavior, the study collected information on individuals' usual travel patterns for different daily routine activities (e.g. commute, grocery shopping, social, and recreational), usual mode, travel time, and distance. As several types of transport modes are available in Bangladesh, for modeling purposes, modes were grouped into six classes: auto (both car and motorbike), bus, walk, cycle, rickshaw, and others (i.e. any mode other than these five).

Questions were asked related to the walking and cycling condition of the neighborhoods to assess it from the residents' viewpoint on a 5 point Likert scale: very poor - poor - moderate - good - very good. A set of perception-based questions was included in this section to reflect the overall condition of respondents' neighborhoods following the same Likert scale. The questions included the perception of walking and cycling conditions in the neighborhood, perceptions of crime situation, and safety from local traffic. Perceptions were explored as a proxy of neighborhood-level characteristics since GIS-based objective measures at the neighborhood-level are unavailable for Rajshahi. For modeling purposes, 'very poor' and 'poor' were aggregated into 'poor' and 'good' and 'very good' were aggregated into 'good' when building the probabilistic model. This was done to avoid having numerous classes with very low frequencies.

An orientation meeting of the surveyors was conducted to introduce them to the survey objectives, expected outcomes, and clarity on each item of information. This was done to ensure that surveyors could gather the required information precisely from the respondents. Three surveyors were employed to conduct face-to-face surveys for approximately two months: July - August 2017. A pilot test was conducted and based on the feedback, some modifications were made to the final questionnaire so that the questions asked became more explicit to the respondents and more relevant to the local contexts.

There are 30 wards in Rajshahi and the survey targeted to collect an equal number of samples from each ward (the initial target was to collect 10 samples from each ward). A random sampling process was followed while choosing a respondent within a ward, and the surveyors were instructed to accept both complete and incomplete surveys. Many persons showed reluctance to participate in the survey, in addition, many of those who participated were unwilling to share information. Because of the presence of missing information among the collected samples, attempts have been made to collect some additional samples. Three hundred fifty-two (352) samples were collected from the 30 wards of Rajshahi. In addition to that, the survey collected samples from the people who live in the surrounding areas of the city. Although the exact number/ portion is unknown, it has been noticed that a significant portion of people lives in the surrounding areas of the city who commute daily to the city. Samples were collected from this group of working segments as we think that it is relevant to explore the AT condition of the city. Fifty (50) random samples were collected from the surrounding areas who commute daily to the city. Thus, a total of 402 samples were collected through the face-to-face survey. Responses with several missing variables were removed and finally, 393 responses with a complete set of variables were taken for final analysis. More details are available in the study by Jamal and Hossain (2020).

3.3. Descriptive Statistics

Table 1 contains the descriptive statistics of the sample. It should be noted that demographic data of the municipality (study area) were not readily available;

however, the district level (Rajshahi municipality is under Rajshahi district) age distribution data of 2015 is available (Bangladesh Bureau of Statistics 2015) and used in this study for comparison purpose. Around 19% of the population belongs to 15 to 24 years age group of Rajshahi district. As one of the focus of the current study is AT users, the percentage of this group is higher in the sample (39.9%). Additionally, being an educational institute oriented city, this segment of the population represents the major portion of the student population who are the primary users of the active modes of travel. For the same reason, 26 to 45 age group represents 45% of the sample, although 32.7% of the population belongs to the same age group. Also, the percentage of older adults living in Rajshahi is low. Overall, only 18.9% of the population belongs to 45 years and over. In the study sample, 7.5% belong to the age group 45 years and over. On average, respondents have at least one bicycle at home. Average income among the households is 35,105 BDT (1 USD = 84 BDT). It should be noted that the average household income of the capital city Dhaka is 55,086 BDT (Power and Participation Research Centre 2016). Forty-two percent of the respondents identified themselves as students, and 37% as full-time employees. A comparison among the population income and occupation group is not possible as up to date city or regional level income and occupation data are not available for Rajshahi. The last available data of Rajshahi city is from a survey of 2001, which we don't think is relevant in the current context as the local conditions such as socio-economic conditions, city characteristics, and modal shares have changed much over the past few years (Jamal and Hossain 2020).

It has been noted in the past (e.g., by Whalen, Páez, and Carrasco 2013) that cycling is a mode that requires some commitment. To discern the differences between different types of bicyclists we use the variable "Daily Bike Time" as a proxy for intensity of cycling. In this way, we classify respondents as non-bicyclists if their daily bike time is zero, and then for other respondents we divide them into quartiles by daily time spent on cycling, as seen in Table 1, with Cyclist Type 1 being the least intensive cyclist and Cyclist Type 4 the most intensive.

There are some important considerations to keep in mind concerning data collection in Bangladesh (also see the research of Aslam et al. 2018 in Pakistan). First, participation in out-of-home activities is very low in Bangladesh, with a national rate of female labor force participation of 36.3% (Hossain 2018). This means that the probability of finding female respondents for commuting data is relatively low to begin with. Secondly, traditional social norms in Bangladesh mean that males usually respond on behalf of their households, and they are culturally disinclined to share information pertaining to female family members. Even females are often not comfortable sharing their information with unknown parties, which is also mentioned by the study of Mitra (2016) in Rajshahi. As a result, almost 85% of the respondents in this study are male. Thus, the sample cannot be said to be representative of the general population.

The study asked the respondents to rate their neighborhoods in different aspects of AT conditions. Overall, three-fourths of the respondents rated their neighborhoods' walking conditions as 'good', which indicates that in general, respondents are satisfied with the walking conditions in their neighborhoods. Almost 54% of the respondents perceive the cycling condition of the neighborhood as good. Seventy percent of the respondents feel secured from the crime during the daylight (rated 'good'). However, respondents don't perceive safety/secured from vehicular traffic while walking on the main roads. Only 28.2% rated perceived safety while walking in the main roads as 'good' and 53% rated their perceived safety as 'moderate'. It is interesting that despite the lack of active transportation infrastructure, most of the respondent rated that walking and

Table 1: Summary statistics of the sample

Variable	Note	Percentage	Mean
Socio-Economic and Demographic Attributes			
Age 1	Dummy variable: 1 if Age 18-25 years	39.9 %	
Age 2	Dummy variable: 1 if Age 26-35 years	27.7 %	
Age 3	Dummy variable: 1 if Age 36-45 years	17.3 %	
Age 4	Dummy variable: 1 if Age More than 45 years	7.6 %	
Gender	Dummy variable: 1 if Male	85 %	
Occupation (Student)	Dummy variable: 1 if Student	41.5 %	
Occupation (Full time employed)	Dummy variable: 1 if Full time employed	36.9 %	
Income	BDT		35105.6
Household Size	Number of people		4.72
Number of vehicles	Number of vehicles		0.49
Number of bicycles	Number of bicycles		0.97
Trip Characteristics			
Commute duration (min)	Minutes		21.08
Duration of daily biking (min)	Minutes		31.82
Cyclist_mode (Non-Bicyclist)	Dummy variable: 1 if respondent's Daily Bike Time = 0	51.7 %	
Cyclist_mode (Cyclist Type 1)	Dummy variable: 1 if respondent's 0 > Daily Bike Time <= 25	14 %	
Cyclist_mode (Cyclist Type 2)	Dummy variable: 1 if respondent's 25 > Daily Bike Time <= 40	10.9 %	
Cyclist_mode (Cyclist Type 3)	Dummy variable: 1 if respondent's 40 > Daily Bike Time <= 115	11.2 %	
Cyclist_mode (Cyclist Type 4)	Dummy variable: 1 if respondent's Daily Bike Time >= 115	12.2 %	
Perceived Social Condition of the Neighborhood			
Perceived safety from crime during the day (poor)	Likert scale	10.9 %	
Perceived safety from crime during the day (moderate)	Likert scale	19.1 %	
Perceived safety from crime during the day (good)	Likert scale	70 %	
Perceived safety while walking in the main roads (poor)	Likert scale	18.6 %	
Perceived safety while walking in the main roads (moderate)	Likert scale	53.2 %	
Perceived safety while walking in the main roads (good)	Likert scale	28.2 %	
Perceived Physical Condition of the Neighborhood			
Perceived walking condition of the neighborhood (poor)	Likert scale	2.5 %	
Perceived walking condition of the neighborhood (moderate)	Likert scale	21.4 %	
Perceived walking condition of the neighborhood (good)	Likert scale	76.1 %	
Perceived cycling condition of the neighborhood (poor)	Likert scale	8.4 %	
Perceived cycling condition of the neighborhood (moderate)	Likert scale	37.7 %	
Perceived cycling condition of the neighborhood (good)	Likert scale	53.9 %	

cycling conditions are 'good', which could be due that respondent besides the lack of adequate pedestrian and cyclist infrastructure, they mostly perceive that physical conditions of the neighborhood regarding walking and cycling are good. This is in line with the finding of Arellana et al. (2019) that reported the existence of heterogeneity of perceptions while evaluating conditions of infrastructure. According to them (Arellana et al. 2019) past experiences can influence individuals' perceptions and differences may exists based on those experiences. For example, people used to live in zones with poor infrastructure could be more tolerant than people that live in zones with better infrastructure.

4. Model

Analysis is based on the application of multinomial logistic regression. Here, it is important to highlight some considerations that impinge on the choice of a modeling approach. Multinomial logistic regression in travel behavior analysis is often nested in the rich behavioral framework of random utility theory (see Train 2009). This model (sometimes called *conditional* logit) requires information on the level of service of the alternative selected by a decision maker, and also on the level of service of the non-chosen alternatives. This poses overwhelming data collection challenges in many regions in the Global South. Some of these challenges are discussed in the context of Bangladesh by Enam and Choudhury (2011).

Information about the non-chosen alternatives can be obtained directly from respondents (which greatly increases respondent burden), or it can be imputed by the analyst. As noted by Enam and Choudhury (2011), choice sets remain unobserved in the data and are not easily deduced from the limited information available in the context of developing countries, especially travel time and cost for non-chose modes. According to Enam and Choudhury (2011), car ownership depends highly on affordability, and very few people in Bangladesh owns a car. Moreover, since published timetables rarely exist, information regarding bus routes are not available. Thus, option to access information regarding transportation via internet or smart phones, which are increasingly common practice in many regions in the world (e.g., Jäppinen, Toivonen, and Salonen 2013) are not available in the local context for this study. Lack of structured transport network data, operations of buses and other transit services beyond their authorized routes, and no fixed routes for non-motorized modes such as rickshaws, make it very difficult for the analyst to define a correct choice set (Enam and Choudhury 2011). The present study also lacks a choice set that contains information on both chosen and non-chosen modes and contains information on the chosen modes only.

The lack of information about the non-chosen modes prevents the use of random utility analysis. Instead, in the analysis, the use of a mode is modeled as the state of an individual for a given commute trip. The probability of individual i having response r can be written as $\pi_i^{(r)} = \Pr(y_i = r)$ where y_i is the unordered categorical response for individual i. If there are J response categories, the model is written as follows:

$$\log \frac{\pi_i^{(r)}}{\pi_i^{(J)}} = (x_i\beta)^{(r)}, r = 1, ..., t-1 \tag{1}$$

The model compares the probabilities of each category t with a base category. A set of contrasting equations with the reference category is estimated where $X^{(r)}$ is a set of predictor variables (x_i) that may be different for each equation (in this study, they are same as it is a probabilistic model) and $\beta^{(r)}$ are the respective estimated coefficients of these variables. For multiple predictor variables, equation 1 can be written as:

$$\log \frac{\pi_i^{(r)}}{\pi_i^{(J)}} = \beta_0^{(r)} + \beta_1^{(r)} x_i + \beta_2^{(r)} x_i + \cdots, r = 1, ..., J-1 \tag{2}$$

Taking the exponential on both sides we can solve for the probabilities as follows:

$$\pi_i^{(r)} = \pi_i^{(J)} e^{\beta_0^{(r)} + \beta_1^{(r)} x_i + \beta_2^{(r)} x_i + \cdots} \tag{3}$$

Then, we can use the fact that the sum of the probabilities for all responses r must be one to derive the following expression:

$$\pi_i^{(J)} = \frac{1}{1 + \sum_i^{J-1} e^{\beta_0^{(i)} + \beta_1^{(i)} x_i + \beta_2^{(i)} x_i + \cdots}} \tag{4}$$

Equation 4 is used to derive the logit probability for response r ($r \neq J$):

$$\pi_i^{(r)} = \frac{e^{\beta_0^{(r)} + \beta_1^{(r)} x_i + \beta_2^{(r)} x_i + \cdots}}{1 + \sum_i^{J-1} e^{\beta_0^{(i)} + \beta_1^{(i)} x_i + \beta_2^{(i)} x_i + \cdots}} \tag{5}$$

This multinomial logit model is estimated using well-established maximum likelihood techniques, which also provide goodness-of-fit indicators, such as AIC and McFadden's ρ^2.

5. Analysis and Results

Table 2 shows the results of a multinomial logistic model of commute mode use, as discussed above. Since the focus of the study is on UAT, walking has been selected as the reference mode. Several variables were tested, and based on their level of significance, some were omitted from the analysis to obtain the final model reported in the table. With the exception of status as a student, other socio-demographic variables did not reach conventional levels of significance (i.e., $p = 0.05$ or better), and were thus omitted from the final model. For some modes, insignificant variables were kept in the model as they have been found significant for another mode/choice. As a result, we included them for every mode. In the final model, walking is the most probable mode of travel, other things being equal. This was followed by bicycle and rickshaw. The number of motorized vehicles in the household is seen to be positively associated with the use of auto and rickshaw. Trip time is positively associated with all modes, which means with the increase in travel time, the probability of walking decreases.

In case of cyclist type, where cyclist type 1 refers to the least intensive cyclists and type 4 refers to be the most intensive cyclist, based on the level of significance, the model results show that with the increase of level of intensity of daily cycling (non-bicyclist being the reference), the probability of choosing cycle as a commute mode increases and the probability of choosing rickshaw and other modes as a commute mode decreases. This suggests that those who cycle daily for a longer duration have a higher probability of cycling for their commute. In addition, although the least intensive cyclists are less likely to choose bus as a commute mode, when the intensity of cycling increases (i.e. daily biking time increases), cyclists are more likely to choose bus a commute mode. Living in a residential area, in contrast, tends to increase the probability of traveling by bus while decreasing the probability of using cycle relative to walking.

The analysis indicates that individual perceptions of neighborhood conditions are significantly correlated with the use of different modes of transportation for commuting. Neighborhood-level social conditions, including higher levels of perceived safety from crime in the neighborhood, tend to associate positively with the UAT and rickshaw use. Also, perceived safety from crime influences auto use. In the Bangladeshi context, auto use can be thought of as a proxy for higher income. Therefore, it seems possible that auto users tend to live in high income neighborhoods, which are generally perceived as safe. Compared to walking, higher level of perceived pedestrian safety from vehicular traffic in the main roads increases the probability of rickshaw, bus, and other modes of transportation and decreases auto use. Perception of the neighborhood level physical conditions is also a significant correlate of mode use. As the level of perceived walking conditions in the neighborhood improves, the probability of walking tends to increase and use of auto, bus and other modes of transportation tend to decrease. Similarly, as the level of perceived cycling condition improves, compared to walking, both cycling and rickshaw see gains and auto, bus and other modes of transportation see decrease in the probability of use.

Table 2: Results of multinomial logistic model

Variable	Cycling	p-val	Rickshaw	p-val	Auto	p-val	Bus	p-val	Other	p-val
Constant	-0.08	0.942	-7.45	0.001	-20.65	0.001	-53.71	0.001	-31.03	0.001
Trip Time (Commute)	0.23	0.001	0.22	0.001	0.18	0.001	0.25	0.001	0.20	0.001
Number of Motorized Vehicles	0.25	0.486	0.74	0.043	0.79	0.027	0.54	0.276	0.52	0.218
Cyclist Type 1	2.85	0.001	-14.60	0.001	0.89	0.269	-14.54	0.001	-12.65	0.001
Cyclist Type 2	-0.99	0.125	-12.10	0.001	0.71	0.446	4.97	0.001	-0.57	0.191
Cyclist Type 3	2.57	0.01	-7.95	0.001	0.44	0.661	16.55	0.001	-5.99	0.001
Cyclist Type 4	1.70	0.375	-6.05	0.033	0.35	0.755	7.55	0.001	-5.52	0.001
Occupation (Student)	-2.11	0.001	-1.20	0.032	-1.39	0.016	0.61	0.413	-3.05	0.001
Perception of Crime Situation in the Neighborhood during the day: Moderate	-0.73	0.2	-1.61	0.005	-2.48	0.001	11.89	0.001	13.99	0.001
Perception of Crime Situation in the Neighborhood during the day: Good	0.57	0.311	1.07	0.062	2.46	0.02	-8.93	0.001	-9.37	0.001
Perception of Pedestrian Safety from Vehicular Traffic in the Main Road: Moderate	0.56	0.339	-1.49	0.01	-0.56	0.532	-0.37	0.652	0.08	0.894
Perception of Pedestrian Safety from Vehicular Traffic in the Main Road: Good	0.47	0.255	1.00	0.016	-0.92	0.096	1.07	0.094	2.16	0.001
Perception of Walking Condition in the Neighborhood: Moderate	-0.65	0.643	0.00	1	17.75	0.001	19.41	0.001	17.69	0.001
Perception of Walking Condition in the Neighborhood: Good	-0.20	0.816	1.00	0.235	-7.93	0.001	-9.00	0.001	-9.77	0.001
Perception of Cycling Condition in the Neighborhood: Moderate	1.27	0.05	1.38	0.074	18.27	0.001	11.73	0.001	15.86	0.001
Perception of Cycling Condition in the Neighborhood: Good	1.48	0.003	1.05	0.042	-11.15	0.001	-6.94	0.001	-8.51	0.001
Land use (Residential)	-1.00	0.073	-0.15	0.79	0.55	0.38	19.64	0.001	-1.09	0.127

Note:
Walking is the reference mode for the model
Initial log-likelihood = -623.19
Final log-likelihood = -321.99
McFadden's $\rho^2 = 0.48$

To better understand the effect on active modes of various perceived environmental conditions, the probabilities of walking and cycling were estimated and plotted as a function of the duration of the trip. At this stage of analysis, we divided the sample into non-student and student population to explore their active commuting patterns, as the literature suggests that the use of active modes for commuting is lower among non-student compared to the student population (Whalen, Páez, and Carrasco 2013; Molina-García, Sallis, and Castillo 2014; Delmelle and Delmelle 2012). Further, we consider different cyclist types from non-bicyclist to the most intensive cyclists, as discussed before. Finally, we also analyze the probabilities of active travel by residential and non-residential land-use types as it has been seen that active commuting behavior can differ by land-use type (Jamal and Hossain 2020). For simulation, we set the number of motorized vehicles to zero. We set the perceptions of conditions of the environment as follows: all perceptions are poor, all perceptions are moderate, all perceptions are good. This includes perceptions about neighborhood's walking condition, safety from traffic while walking, and crime situation during daytime. Perceptions of cycling were not aggregated for this and treated as a separate variable. The probabilities were simulated by commute travel time, ranging from 0-30 min. These values of travel times were chosen because approximately 80% of all commute trips reported were within this range.

Figure 1 and Figure 2 show the simulated probabilities for non-students in residential and non-residential land-use by perceptions of the environment and perceptions of cycling. A few interesting trends have become apparent. Non-students whose trips start in a location with residential land-uses display a probability of walking for longer trips that increases with the improvement of the perceived neighborhood environment (i.e., of walking, safety from traffic and crime situations). The rate of increase is higher for non-bicyclists compared to cyclists. Combining the improvement of perceived cycling conditions with the other perceived neighborhood environmental conditions, there is a relatively smaller increase in the probability of walking for both cyclists and non-cyclists and the increase rate is still higher for non-bicyclists. This indicates that non-bicyclists are more likely to walk for longer duration of commute when perceived cycling and other environmental conditions are improved. In terms of cycling, the probability of using bicycle for longer trips among non-student cyclists increases rapidly when cycling conditions in the neighborhood are improved in the neighborhood, and the rate of increase is higher in non-residential land-uses compared to residential land-uses. For non-bicyclists (and non-students), other perceived environmental conditions seem to influence their probability of choosing cycle as a commute mode for longer duration more compared to perceived cycling conditions. The possible reason could be that as they do not use cycle at all, they are less able to evaluate the cycling condition in their neighborhoods, thus emphasizing other environmental conditions they experience regularly.

Figure 3 and Figure 4 show the simulation for students in residential and non-residential land-use by perceptions of the environment and perceptions of cycling. Similar to the non-student population, in both residential and non-residential land-uses, students' probability of walking for longer duration of commute increases with the improvement of perceived environmental conditions and the rate of increase is higher for non-bicyclists compared to cyclists. Although, after combining the perceived cycling conditions with other environmental conditions, the probability of walking for longer commute still increases, the rate of increase is less compared to the perceived improvements in the environmental conditions. Probability of cycling for longer duration of commute is higher in the non-residential land-uses compared to residential land-uses. With the improvements of perceived environmental conditions as well as perceived cycling conditions,

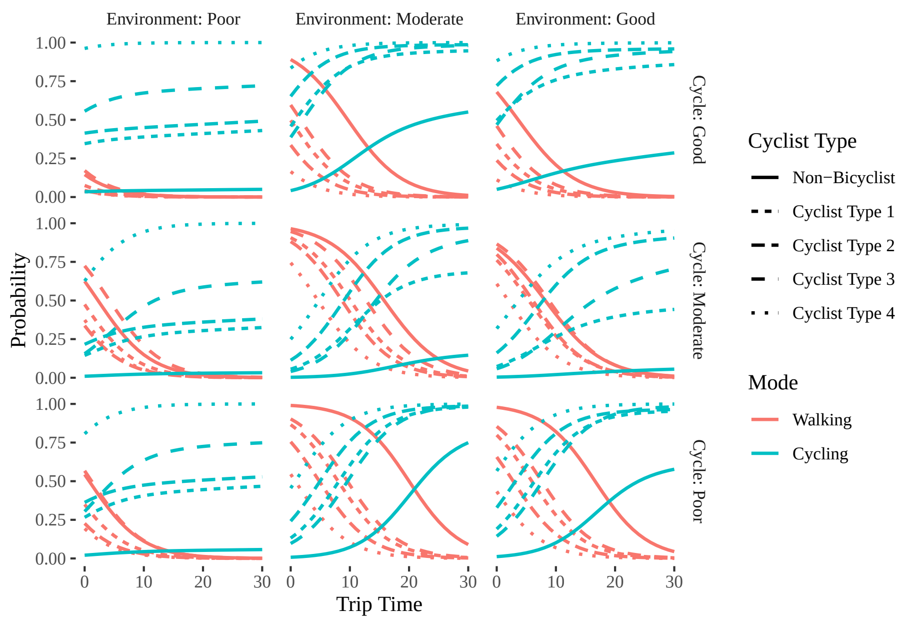

Figure 1: Probabilities of active modes under perceived conditions of the environment in the neighborhood (crime, conditions for walking, safety from traffic when walking) vs perceived conditions for cycling, by cycling level of traveller (non-students in residential land uses).

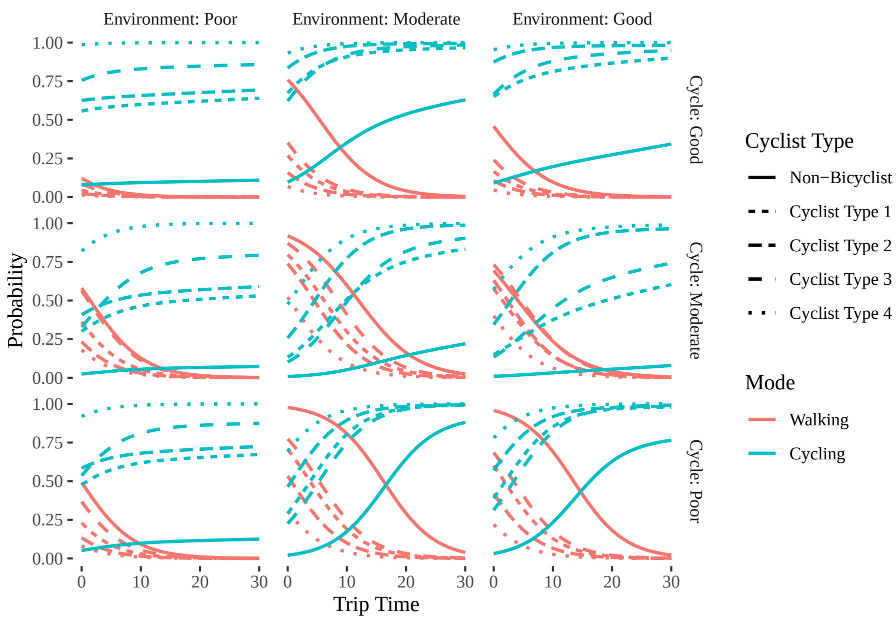

Figure 2: Probabilities of active modes under perceived conditions of the environment in the neighborhood (crime, conditions for walking, safety from traffic when walking) vs perceived conditions for cycling, by cycling level of traveller (non-students in non-residential land uses).

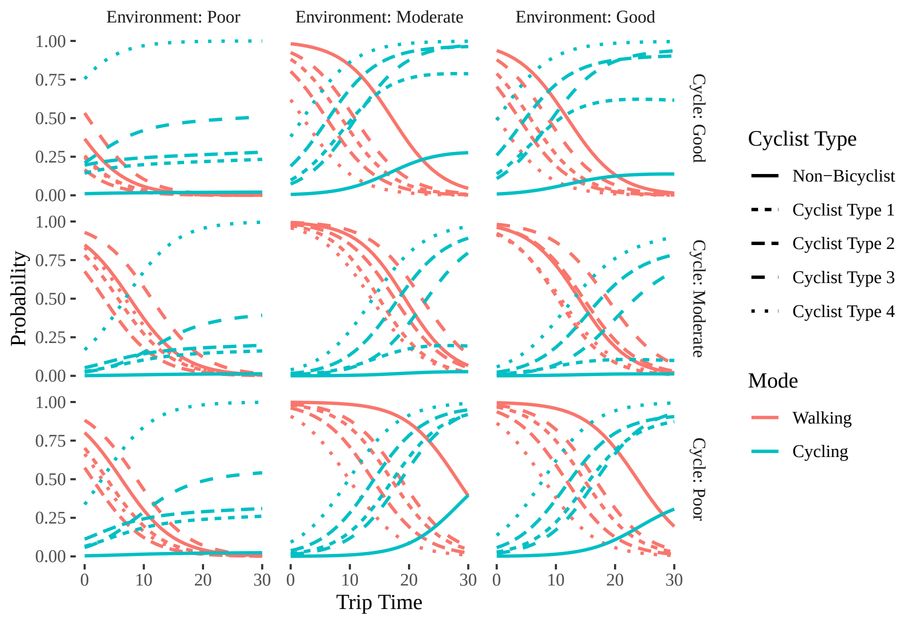

Figure 3: Probabilities of active modes under perceived conditions of the environment in the neighborhood (crime, conditions for walking, safety from traffic when walking) vs perceived conditions for cycling, by cycling level of traveller (students in residential land uses).

even student non-bicyclists show a higher probability of cycling for commute for longer duration in non-residential land-uses compared to residential land-uses. For cyclists, improvements in environmental conditions along with cycling conditions increase the probability of cycling for longer duration of commute and the rate is higher in non-residential land-uses than in residential land-uses.

It would be interesting to see what other aspects of the environment besides cycling conditions contribute to the probability of travel by active modes. For instance, one might question whether to prioritize efforts to improve perception of crime or perception of walking conditions. To explore this, we proceed next to simulate the probabilities for non-students and students for both residential and non-residential land-use as follows: we set the perception of cycling to good, and perceptions of walking (walking and safety while walking) to poor, moderate,

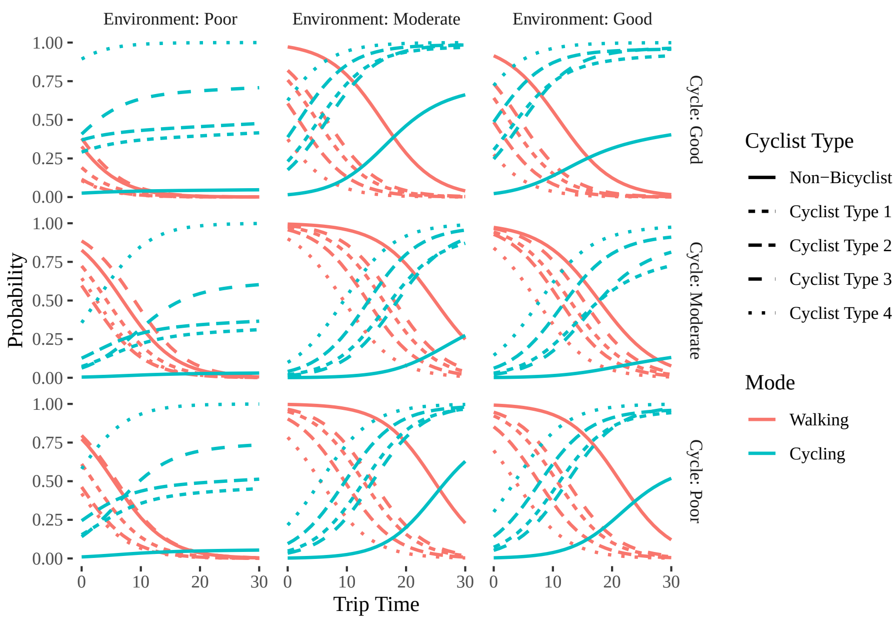

Figure 4: Probabilities of active modes under perceived conditions of the environment in the neighborhood (crime, conditions for walking, safety from traffic when walking) vs perceived conditions for cycling, by cycling level of traveller (students in non-residential land uses).

and good. This time, we kept the perceptions of crime during daytime as a separate variable. We simulate these probabilities by travel time, ranging from 0-30 min. The number of motorized vehicles was set to zero.

Figure 5 and Figure 6 show the simulated probabilities of non-students' active mode use by perceptions of walking and perceptions of crime as a function of travel time for residential and non-residential land-use, where perceived cycling conditions is good. In both land-uses, the probability of non-bicyclists to use bicycle for longer duration of commute increases when perceived walking conditions improve from 'poor' to 'moderate'. This means that along with 'good' cycling conditions, improvement in the walking condition increases the probability of cycling for commute for non-bicyclists. For non-student cyclists, improvement in the walking and crime conditions increases their probability of cycling for longer duration of commute and the rate is higher in non-residential land-uses compared to residential land-use. Figure 7 and Figure 8 shows the simulation corresponding to students by residential and non-residential land-use types. A comparison with the preceding figures indicates that students use active modes more compared to non-students. With the improvement of walking and crime conditions, the probability of walking for longer duration of commute increases for non-bicyclists in both land-use types. The probability of student non-bicyclists of using bicycle for longer trips increases by improving the walking conditions in the neighborhood (recall that in this simulation cycling condition is already set to 'good') and the rate of increase is higher in non-residential land-use compared to residential land-use. For student cyclists, the probability of using bicycle for longer duration of commute increases with the improvement of walking and crime conditions in the neighborhood and the rate of increase is higher in the non-residential areas compared to residential areas.

Figure 9 and Figure 10 show the net change in probabilities by active modes

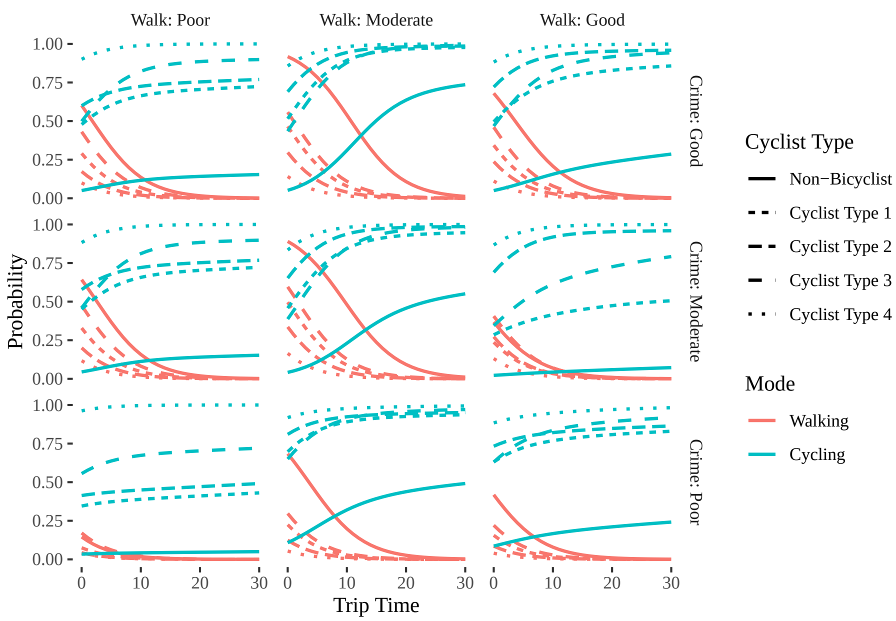

Figure 5: Probabilities of active mode use when perceived conditions for cycling are good: perceived conditions for walking in the neighborhood (conditions for walking, safety from traffic when walking) vs perceived crime, by cycling level of traveller (non-students in residential landuse).

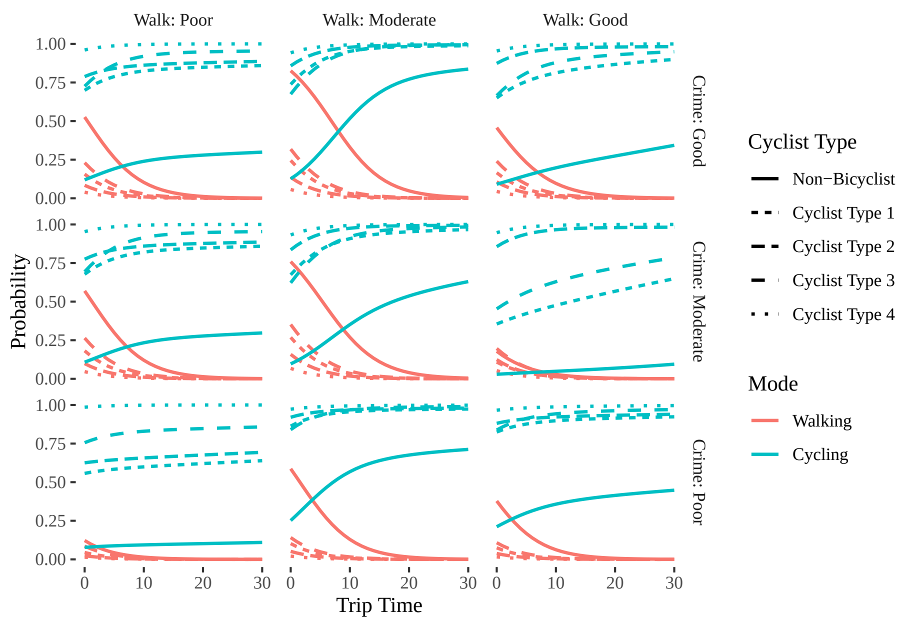

Figure 6: Probabilities of active mode use when perceived conditions for cycling are good: perceived conditions for walking in the neighborhood (conditions for walking, safety from traffic when walking) vs perceived crime, by cycling level of traveller (non-students in non-residential landuse).

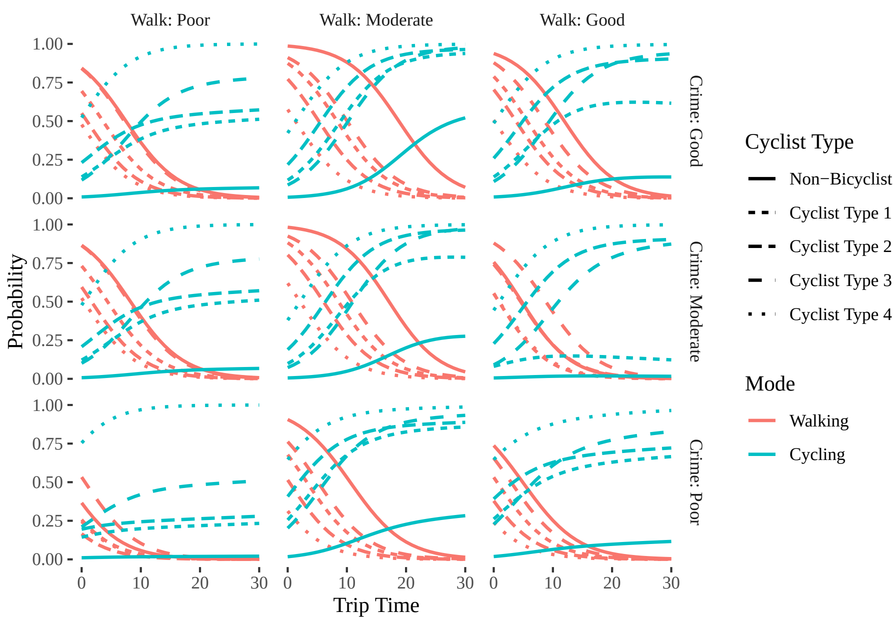

Figure 7: Probabilities of active mode use when perceived conditions for cycling are good: perceived conditions for walking in the neighborhood (conditions for walking, safety from traffic when walking) vs perceived crime, by cycling level of traveller (students in residential landuse).

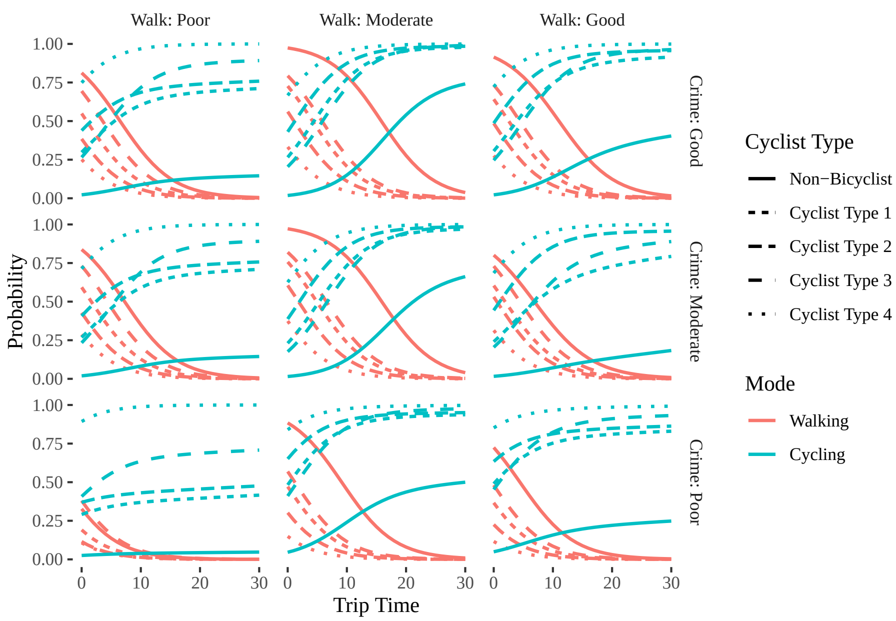

Figure 8: Probabilities of active mode use when perceived conditions for cycling are good: perceived conditions for walking in the neighborhood (conditions for walking, safety from traffic when walking) vs perceived crime, by cycling level of traveller (students in non-residential landuse).

for non-students in residential and non-residential land-uses respectively when perceived conditions for cycling are good: perceived conditions for walking in the neighborhood (conditions for walking, safety from traffic when walking) vs perceived conditions for crime change. In both cases, net increase in probability of using active modes is higher for non-bicyclist compared to cyclists, which is expected as cyclists are already cycling daily at different levels of intensity. For non-student non-bicyclists, probability of walking for longer duration of commute increases with the improvement in walking and crime condition in the neighborhood and the rate is higher in the non-residential land-uses compared to residential land-uses. On the other hand, their probability of cycling for longer duration of commute increases when walking conditions is improved from 'poor' to 'moderate' and crime conditions from 'poor' to 'good'. However, when walking conditions improved from 'moderate' to 'good' and with the improvement in the crime conditions, the probabilities of non-students non-bicyclists' active mode use decreases. One possible explanation could be that improved neighborhood conditions indicate affluent neighborhoods, which means that high income households live there among whom active modes are not popular and they usually use auto and rickshaw for their daily travel. Similar trend has been noticed for the student non-bicyclists in Figure 11 and Figure 12 which show the net change in probabilities by active modes for students in residential and non-residential land-uses respectively. Additionally, with improvement in the walking conditions from 'poor' to 'moderate' and crime conditions from 'poor' to 'good', student cyclists tend to use cycle for longer duration of commute and the rate of increase is higher compared to student non-bicyclists.

Figure 13 and Figure 14 show the net change in probabilities by active modes for non-students in residential and non-residential land-uses respectively when perceived conditions for cycling are good: perceived conditions for crime change

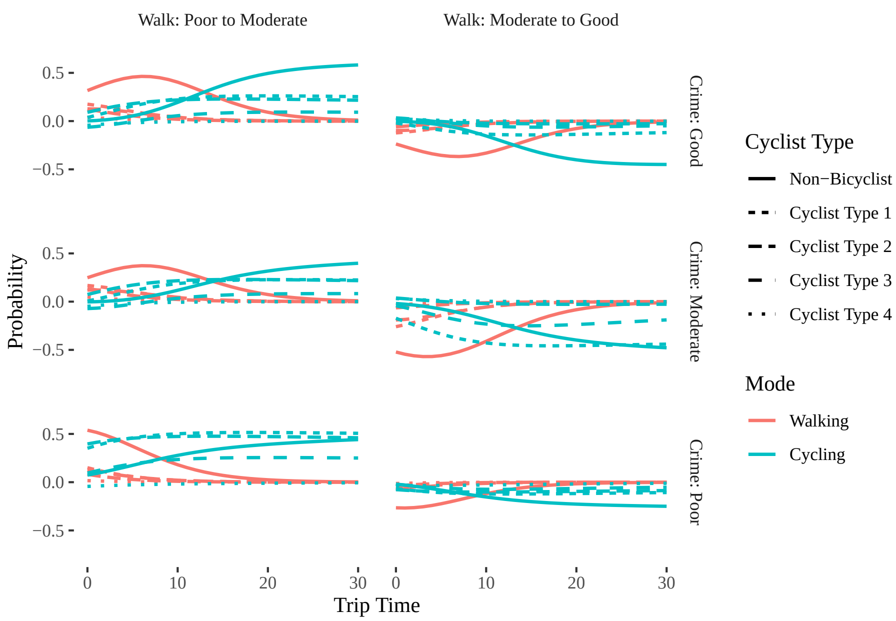

Figure 9: Net change in probabilities of active mode use when perceived conditions for cycling are good: perceived conditions for walking in the neighborhood change (conditions for walking, safety from traffic when walking) vs perceived crime, by cycling level of traveller (non-students in residential landuse).

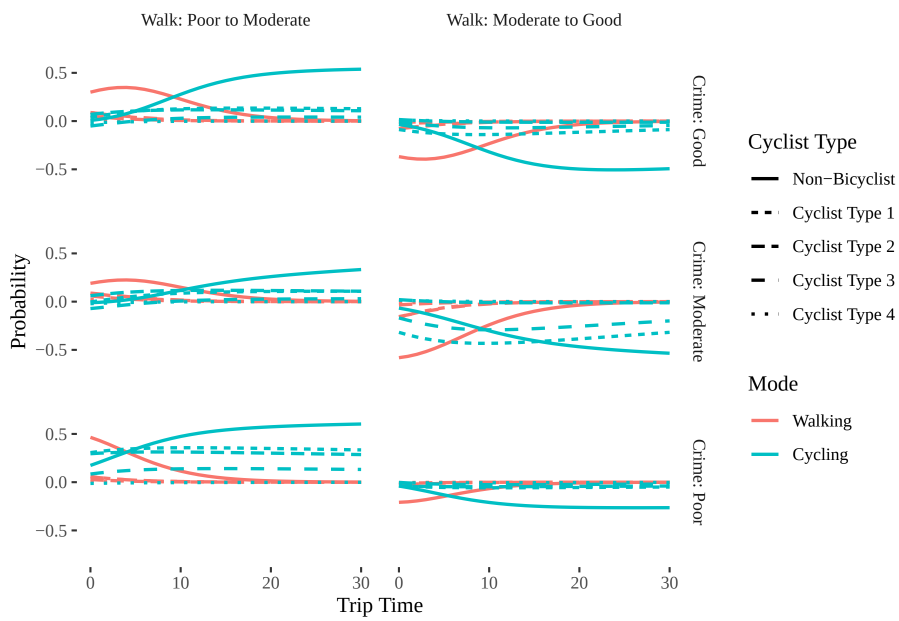

Figure 10: Net change in probabilities of active mode use when perceived conditions for cycling are good: perceived conditions for walking in the neighborhood change (conditions for walking, safety from traffic when walking) vs perceived crime, by cycling level of traveller (non-students in non-residential landuse).

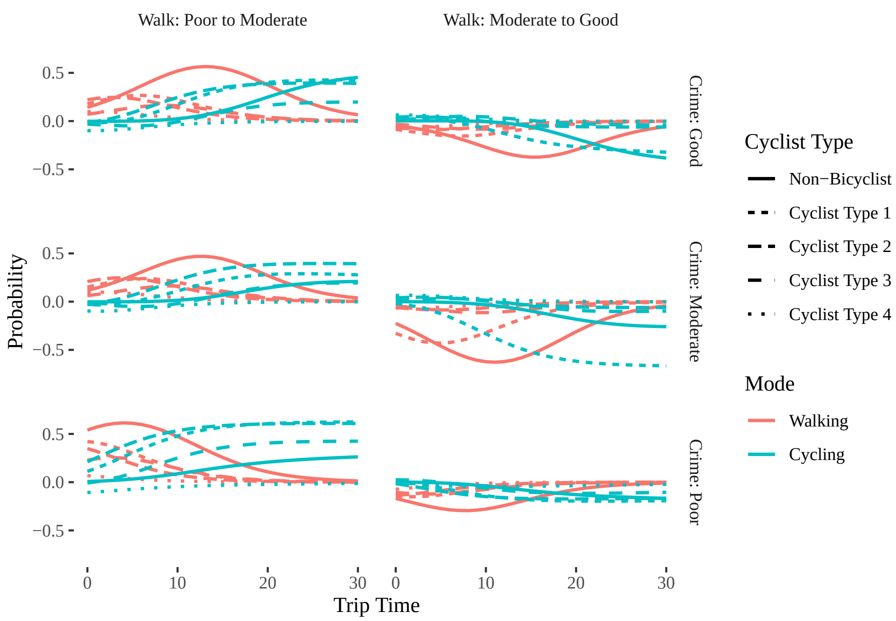

Figure 11: Net change in probabilities of active mode use when perceived conditions for cycling are good: perceived conditions for walking in the neighborhood change (conditions for walking, safety from traffic when walking) vs perceived crime, by cycling level of traveller (students in residential landuse).

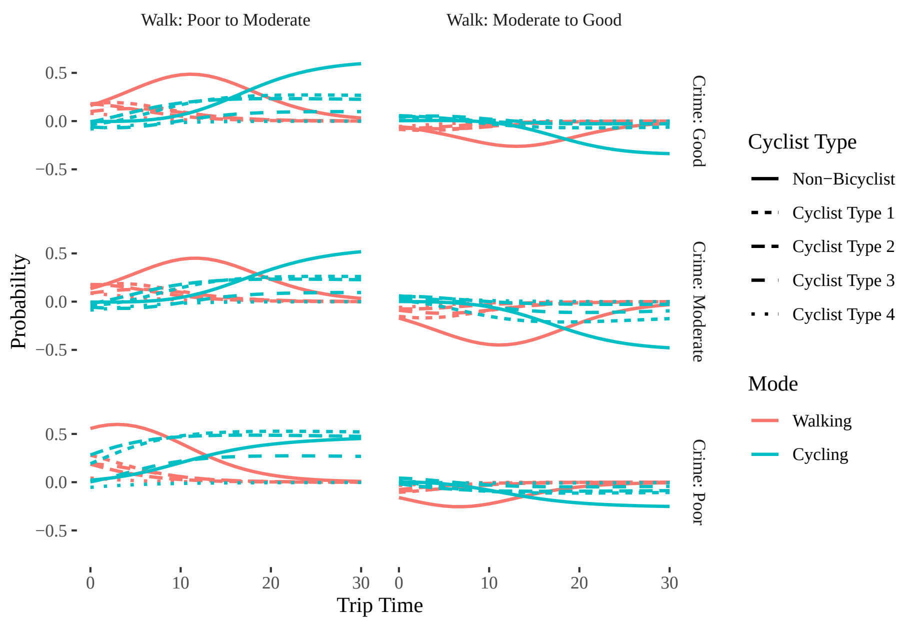

Figure 12: Net change in probabilities of active mode use when perceived conditions for cycling are good: perceived conditions for walking in the neighborhood change (conditions for walking, safety from traffic when walking) vs perceived crime, by cycling level of traveller (students in non-residential landuse).

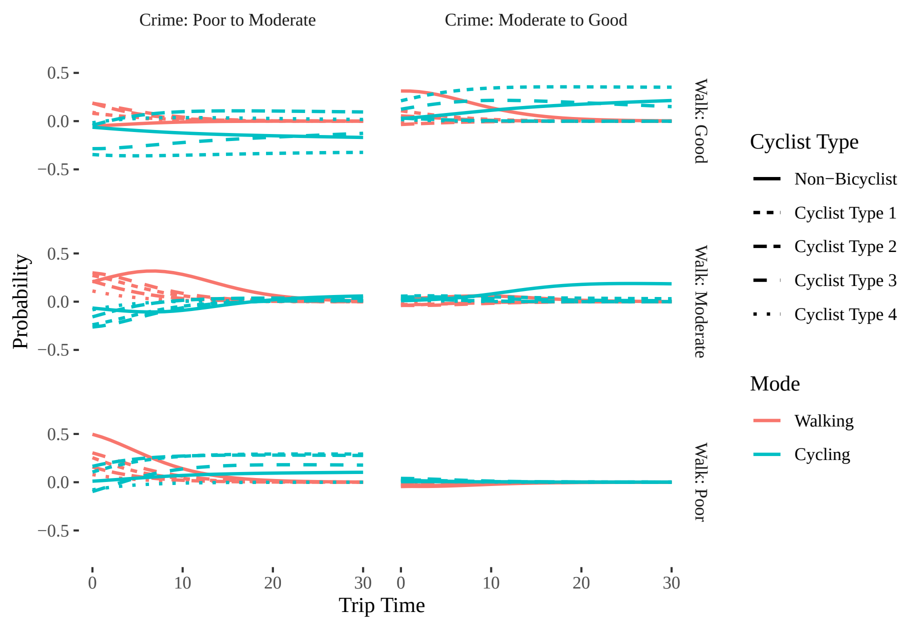

Figure 13: Net change in probabilities of active mode use when perceived conditions for cycling are good: perceived conditions for crime change vs perceived conditions for walking in the neighborhood (conditions for walking, safety from traffic when walking), by cycling level of traveller (non-students in residential land use).

vs perceived conditions for walking in the neighborhood (conditions for walking, safety from traffic when walking). No significant change is observed in both cases. Figure 15 and Figure 16 show the net change in probabilities by active modes for students in residential and non-residential land-uses respectively when perceived conditions for cycling are good: perceived conditions for crime change vs perceived conditions for walking in the neighborhood (conditions for walking, safety from traffic when walking). For students, probability of using active modes increases when crime condition in the neighborhood increases from ‘poor’ to ‘moderate’ and walking condition improves from ‘poor’ to ‘moderate’ and the change is higher for cyclists compared to non-cyclists.

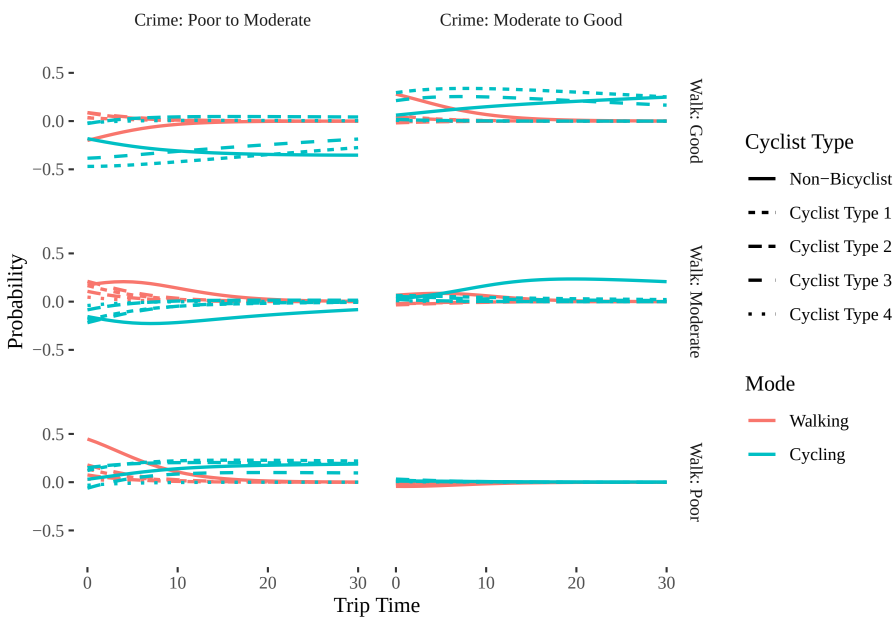

Figure 14: Net change in probabilities of active mode use when perceived conditions for cycling are good: perceived conditions for crime change vs perceived conditions for walking in the neighborhood (conditions for walking, safety from traffic when walking), by cycling level of traveller (non-students in non-residential land use).

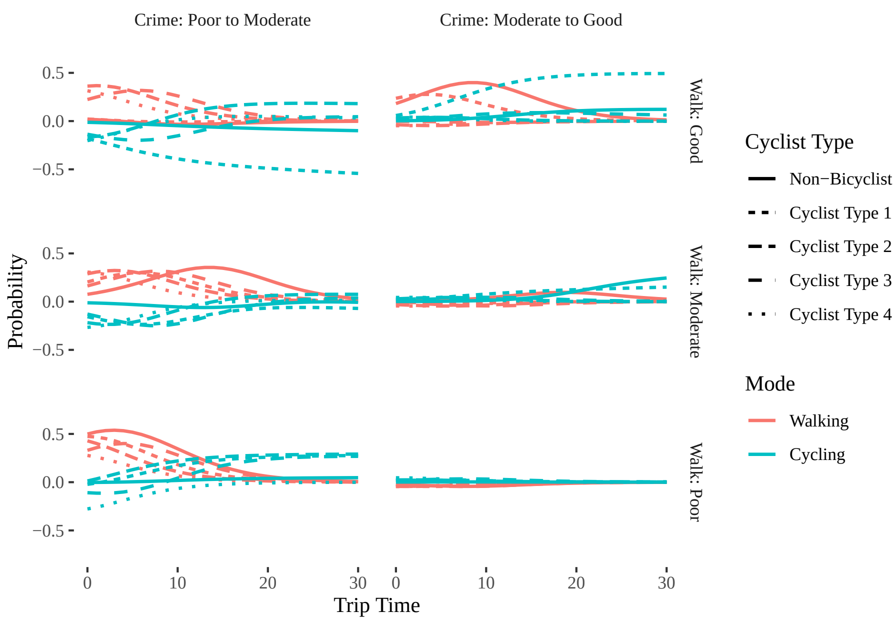

Figure 15: Net change in probabilities of active mode use when perceived conditions for cycling are good: perceived conditions for crime change vs perceived conditions for walking in the neighborhood (conditions for walking, safety from traffic when walking), by cycling level of traveller (students in residential land use).

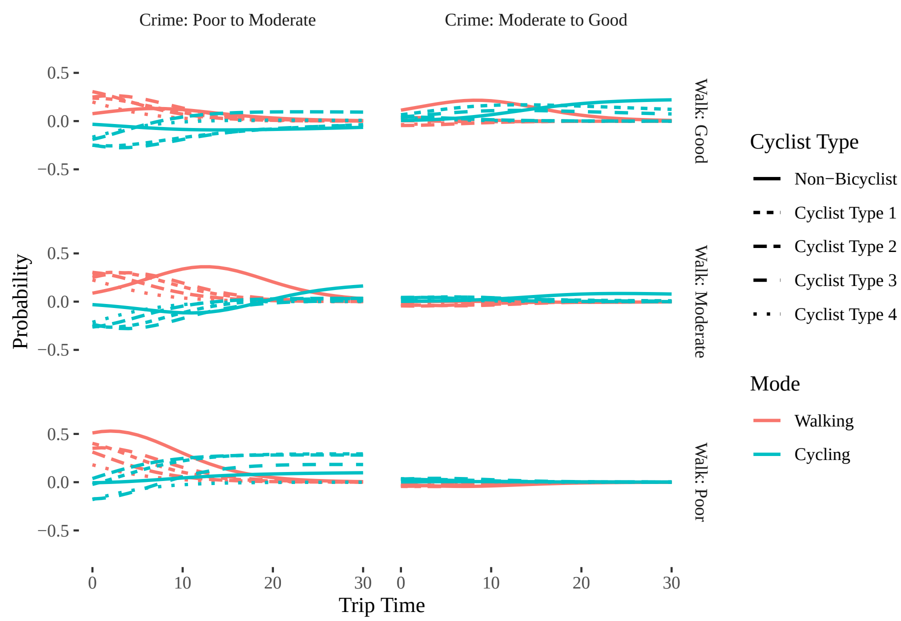

Figure 16: Net change in probabilities of active mode use when perceived conditions for cycling are good: perceived conditions for crime change vs perceived conditions for walking in the neighborhood (conditions for walking, safety from traffic when walking), by cycling level of traveller (students in non-residential land use).

6. Conclusion

This paper explored the correlates of UAT in the context of a city in the Global South. The study area was the city of Rajshahi, known as the Education City of Bangladesh. Along with socio-demographic and trip characteristics, environmental correlates such as individuals' perceptions of social (crime and traffic safety) and physical (walking and cycling) conditions in the neighborhood were studied. To the authors' best knowledge, this is among the earliest studies that explored the association between individuals' perceptions and the probability of traveling by different modes in Rajshahi, Bangladesh. The study provided an understanding of how travel by active modes is affected by individual perceptions of the social and physical conditions in the neighborhood, in addition to individual attributes. There are differences in socio-cultural contexts between the cities in the Global South vs. Global North. Also, socio-cultural contexts within the Global South cities are different. As there are limited evidence in the context of the South Asian cities, it is hard to claim that the results of this study are generalizable to other South Asian cities. More studies in these areas are needed to reach a concrete conclusion.

The study found that students are more probable users of active modes of transportation, which is similar to findings reported in developed countries (e.g., Whalen, Páez, and Carrasco 2013; Molina-García, Sallis, and Castillo 2014; Delmelle and Delmelle 2012). The results of the study showed that regular cyclists are more likely to use cycle as a commute mode compared to non-bicyclists, which indirectly echoes the findings of Acheampong (2017) and Srinivasan, Pradhan, and Naidu (2007) in the Global South contexts where they found cycle ownership and higher frequency of using a cycle increases the likelihood of being an active commuter. The results of the current study also revealed that the number of motorized vehicles in the household increases the chance of using auto or rickshaw for commuting, which is expected in the Bangladeshi context. In Bangladesh, ownership of a motorized vehicle can be considered as a proxy for high income (Enam and Choudhury 2011). There is a fare associated with rickshaw, which makes them comparatively expensive to UAT modes. Furthermore, rickshaw seems to provide some reassurance against poor perceptions of crime. Thus, those who own motorized vehicles are more likely to use auto and rickshaw compared to UAT modes for their commute. Similar to the findings of Srinivasan, Pradhan, and Naidu (2007), the study findings indicate that motorized vehicle ownership discourages active commute. Overall, it can be concluded from the results that students and individuals with low income are more likely to use UAT modes compared to other socio-demographic groups. Thus, policy practitioners should consider initiating programs to encourage motorized vehicle owners as well as high income groups in walking and cycling, and/or rewarding active travel in other ways.

This study supports the findings from previous transportation studies where it has been seen that the probability of walking decreases with the increase in travel time. However, by assessing the probability of mode use in different scenarios (i.e. perceived environmental conditions), this study revealed that with the increase in the level of perceptions about the neighborhood conditions, the probability of active modes, can be increased for longer trips. Non-bicyclists tend to walk and cyclists tend to cycle for longer duration of commute with the perceived improvement in the environmental conditions. Non-bicyclists also show higher probability of using cycle for commute when perceived environmental conditions are improved. Probability of using cycle for commute is higher in non-residential land-uses compared to residential land-uses. Also, simulation of different scenarios suggests that with the perceived improvements in environmental conditions, students are more likely to use active modes compared to non-students.

It has been seen that the use of cycle for commuting is more common among regular cyclists compared to non-bicyclists. The findings show that the probability of using cycle increases with the improvement of cycling conditions in the neighborhood. Also, when perceived cycling condition is good, improvement of perceived walking condition, safety from traffic and crime conditions in the neighborhood can positively influence the probability of choosing cycle as a commute mode for longer duration of travel. Under similar circumstances, the probability of walking for commute also increases, although the trip duration is less than cycling. The simulation of different scenarios suggests that the probability of choosing cycle as a commute mode is more likely to be increased by improving perceptions of walking conditions from poor to moderate along with increasing perceived crime conditions. Also, it has been seen that the rate of increase of probability will be higher for the improvement of walking conditions (poor to moderate) compared to the improvement of crime condition. Although non-bicyclists tend to use a variety of modes for commute, with the improvement of environmental conditions, cyclists seem to prefer cycle as their commute mode. Policy implication of this finding is that at first, individuals need to be encouraged in cycling on a regular basis, which will, therefore, increase the probability of more people using cycle as a commute mode. Policies and programs to improve perceptions, such as improving the condition and ensuring safety from vehicular traffic (e.g. traffic signals, traffic calming measures) and crime situations in the neighborhood can be useful to increase the value of cycling. In the longer term, perceptions and attitudes can be influenced by developing and designing walking- and cycling-friendly neighborhoods. For example, improvement of physical conditions such as development of UAT supportive infrastructure (e.g. sidewalks, bike lanes) will increase the probability of active travel. Also, UAT related promotional activities could be introduced to address the negative perceptions towards UAT and creating awareness regarding the benefits of active travel, which is also proposed by the study of Rosas-Satizábal and Rodriguez-Valencia (2019) for Bogota, Columbia.

The present study has some limitations that are endemic to studies in the Global South. First, the study was cross-sectional and not part of a recurring data collection effort; for this reason, causal effects cannot be established. Second, detailed data on built-environment characteristics (say in a GIS) are unavailable for Rajshahi, Bangladesh, which is why the research used self-reported perceptions by users. Thus, although previous research has shown that perceptions of the environment show remarkable geographical consistency (Paez 2013), studying objective conditions of the built-environment was not possible in this research. Collecting direct built-environment measures should be emphasized so that future studies can incorporate them to establish more quantifiable associations between active modes and environmental factors - thus can assist the evaluation of the potential impact of built-environment related interventions on travel by active modes. Micro- or neighborhood-level data on traffic collisions and crime rates in the study areas were also unavailable - which can be a scope for future research. Although it was beyond the scope of the study to collect information on non-chose modes of commute for the respondents, it would be interesting to develop a mode choice model with a full choice set data. The level of service variables for the different modes were not available for this case study, but should such variables become available, estimating a latent class choice model would become a new avenue for research. Future studies could also focus on age-specific and gender-specific UAT mode use as in developed countries, it has been seen in other literature that environmental factors affect different age groups differently (Sallis et al. 2007). Nevertheless, the present study contributes towards building a better understanding of how perceptions towards neighborhood level social and physical conditions influence the use of UAT modes for commuting, which can be used as a basis for developing travel mode change interventions in the context of Global South with similar socio-cultural characteristics.

7. Acknowledgments

The authors would like to thank the Bangladesh Institute of Planners for their 'Small Grant for Research' for financial support in this study. Special thanks are due to the surveyors who completed the field work and all survey participants. The following `R` packages were used in the course of this research, and the authors would like to acknowledge their developers: `ggthemes` (Arnold 2019); `kableExtra` (Zhu 2019); `knitr` (Xie 2014, 2015); `nnet` (Venables and Ripley 2002); `pandocfilters` (Schwendinger and Hornik 2019); `readxl` (H. Wickham and Bryan 2019); `reshape2` (Wickham 2007); `rticles` (Allaire et al. 2020); `textreg` (Miratrix 2018); `tidyverse` (H. Wickham et al. 2019); and `tinytex` (Xie 2019, 2020).

References

Acheampong, Ransford A. 2017. "Towards Sustainable Urban Transportation in Ghana: Exploring Adults' Intention to Adopt Cycling to Work Using Theory of Planned Behaviour and Structural Equation Modelling." *Transportation in Developing Economies* 3 (2): 18.

Adams, Jean. 2010. "Prevalence and Socio-Demographic Correlates of 'Active Transport' in the Uk: Analysis of the Uk Time Use Survey 2005." *Preventive Medicine* 50 (4): 199–203.

Adlakha, Deepti, J Aaron Hipp, and Ross C Brownson. 2016a. "Neighborhood-Based Differences in Walkability, Physical Activity, and Weight Status in India."

Journal of Transport & Health 3 (4): 485–99.

Adlakha, Deepti, J Hipp, and Ross Brownson. 2016b. "Adaptation and Evaluation of the Neighborhood Environment Walkability Scale in India (News-India)." *International Journal of Environmental Research and Public Health* 13 (4): 401.

Adlakha, Deepti, J Hipp, James Sallis, and Ross Brownson. 2018. "Exploring Neighborhood Environments and Active Commuting in Chennai, India." *International Journal of Environmental Research and Public Health* 15 (9): 1840.

Ajzen, I. 1985. "From Intentions to Actions: A Theory of Planned Behavior." Book Section. In *Action-Control: From Cognition to Behavior*, edited by J. Kuhl and J. Beckman, 11–39. Heidelberg: Springer.

Akar, Gulsah, and Kelly J Clifton. 2009. "Influence of Individual Perceptions and Bicycle Infrastructure on Decision to Bike." Journal Article. *Transportation Research Record* 2140 (1): 165–72.

Allaire, JJ, Yihui Xie, R Foundation, Hadley Wickham, Journal of Statistical Software, Ramnath Vaidyanathan, Association for Computing Machinery, et al. 2020. *Rticles: Article Formats for R Markdown*. https://CRAN.R-project.org/package=rticles.

Arellana, Julian, Maria Saltarin, Ana Margarita Larranaga, Vilma Alvarez, and Cesar Augusto Henao. 2020. "Urban Walkability Considering Pedestrians' Perceptions of the Built Environment: A 10-Year Review and a Case Study in a Medium-Sized City in Latin America." *Transport Reviews* 40 (2): 183–203.

Arellana, Julian, Maria Saltarin, Ana Margarita Larranaga, Virginia I Gonzlez, and Cesar Augusto Henao. 2020. "Developing an Urban Bikeability Index for Different Types of Cyclists as a Tool to Prioritise Bicycle Infrastructure Investments." *Transportation Research Part A: Policy and Practice* 139: 310–34.

Arellana, Julián, Luis Fuentes, Joyce Cantillo, and Vilma Alvarez. 2019.

"Multivariate Analysis of User Perceptions About the Serviceability of Urban Roads: Case of Barranquilla." *International Journal of Pavement Engineering*, 1–10.

Arnold, Jeffrey B. 2019. *Ggthemes: Extra Themes, Scales and Geoms for 'Ggplot2'*. https://CRAN.R-project.org/package=ggthemes.

Aslam, S Atif Bilal, Houshmand E Masoumi, Muhammad Asim, and Izza Anwer Minhas. 2018. "Cyclability in Lahore, Pakistan: Looking into Potential for Greener Urban Traveling." *Tema. Journal of Land Use, Mobility and Environment* 11 (3): 323–43.

Auckland Transport. 2016. "Measuring and Growing Active Modes of Transport in Auckland." https://at.govt.nz/media/1957535/at_active-modes-2016.pdf.

Bangladesh Bureau of Statistics. 2013. "District Statistics 2011, Rajshahi." Statistics and Information Division, Ministry of Planning. Government of the People's Republic of Bangladesh.

———. 2015. "Population Monograph of Bangladesh. Age-Sex Composition of Bangladesh Population." Statistics and Information Division, Ministry of Planning. Government of the People's Republic of Bangladesh.

Brunsdon, Chris, and Alexis Comber. 2020. "Opening Practice: Supporting Reproducibility and Critical Spatial Data Science." Journal Article. *Journal of Geographical Systems*. https://doi.org/10.1007/s10109-020-00334-2.

Buehler, Ralph, John Pucher, Dafna Merom, and Adrian Bauman. 2011. "Active Travel in Germany and the Us: Contributions of Daily Walking and Cycling to Physical Activity." *American Journal of Preventive Medicine* 41 (3): 241–50.

Carroll, P., B. Caulfield, and A. Ahern. 2019. "Modelling the Potential Benefits of Increased Active Travel." Journal Article. *Transport Policy* 79: 82–92.

https://doi.org/10.1016/j.tranpol.2019.04.020.

Cerin, Ester, Eva Leslie, and Neville Owen. 2009. "Explaining Socio-Economic Status Differences in Walking for Transport: An Ecological Analysis of Individual, Social and Environmental Factors." *Social Science & Medicine* 68 (6): 1013–20.

Cerin, Ester, Cindy HP Sit, Anthony Barnett, Janice M Johnston, Man-Chin Cheung, and Wai-Man Chan. 2014. "Ageing in an Ultra-Dense Metropolis: Perceived Neighbourhood Characteristics and Utilitarian Walking in Hong Kong Elders." *Public Health Nutrition* 17 (1): 225–32.

Cervero, Robert. 2013. "Linking Urban Transport and Land Use in Developing Countries." *Journal of Transport and Land Use* 6 (1): 7–24.

———. 2014. "Transport Infrastructure and the Environment in the Global South: Sustainable Mobility and Urbanism." Journal Article. *Journal of Regional and City Planning* 25 (3): 174–91.

Cleland, V. J., A. Timperio, and D. Crawford. 2008. "Are Perceptions of the Physical and Social Environment Associated with Mothers' Walking for Leisure and for Transport? A Longitudinal Study." Journal Article. *Preventive Medicine* 47 (2): 188–93. ISI:000258560300008%0Ahttp://ac.els-cdn.com/S0091743508002703/1-s2.0-S0091743508002703-main.pdf?_tid=128949ee-0453-11e7-8058-00000aacb360&acdnat=1489014229_97f3dd694b9003d735c51e638c70027f.

Delmelle, Eric M, and Elizabeth Cahill Delmelle. 2012. "Exploring Spatio-Temporal Commuting Patterns in a University Environment." *Transport Policy* 21: 1–9.

Dill, Jennifer, and Kim Voros. 2007. "Factors Affecting Bicycling Demand: Initial Survey Findings from the Portland, Oregon, Region." *Transportation Research Record* 2031 (1): 9–17.

Enam, Annesha, and Charisma F Choudhury. 2011. "Methodological Issues in Developing Mode Choice Models for Dhaka, Bangladesh." *Transportation Research Record* 2239 (1): 84–92.

Gatersleben, B., and K. M. Appleton. 2007. "Contemplating Cycling to Work: Attitudes and Perceptions in Different Stages of Change." Journal Article. *Transportation Research Part A-Policy and Practice* 41 (4): 302–12. https://doi.org/10.1016/j.tra.2006.09.002.

Giles-Corti, Billie, and Robert J Donovan. 2002. "Socioeconomic Status Differences in Recreational Physical Activity Levels and Real and Perceived Access to a Supportive Physical Environment." *Preventive Medicine* 35 (6): 601–11.

Godefrooij, T, and S Schepel. 2010. "Co-Benefits of Cycling-Inclusive Planning and Promotion." *World Bank, Netherlands*.

Gomes, Grace AO, Rodrigo S Reis, Diana C Parra, Isabela Ribeiro, Adriano AF Hino, Pedro C Hallal, Deborah C Malta, and Ross C Brownson. 2011. "Walking for Leisure Among Adults from Three Brazilian Cities and Its Association with Perceived Environment Attributes and Personal Factors." *International Journal of Behavioral Nutrition and Physical Activity* 8 (1): 111.

Government of Bangladesh. 2013. "National Integrated Multimodal Transport Policy." Government of the People's Republic of Bangladesh.

Gómez, Luis F, Diana C Parra, David Buchner, Ross C Brownson, Olga L Sarmiento, José D Pinzón, Mauricio Ardila, José Moreno, Mauricio Serrato, and Felipe Lobelo. 2010. "Built Environment Attributes and Walking Patterns Among the Elderly Population in Bogotá." *American Journal of Preventive Medicine* 38 (6): 592–99.

Grosse, J., A. S. Olafsson, T. A. Carstensen, and C. Fertner. 2018. "Exploring the Role of Daily "Modality Styles" and Urban Structure in Holidays and Longer Weekend Trips: Travel Behaviour of Urban and Peri-Urban Residents in Greater

Copenhagen." Journal Article. *Journal of Transport Geography* 69: 138–49. https://doi.org/10.1016/j.jtrangeo.2018.04.008.

Gul, Yasmeen, Zahid Sultan, and Gul Ahmed Jokhio. 2018. "The Association Between the Perception of Crime and Walking in Gated and Non-Gated Neighbourhoods of Asian Developing Countries." *Heliyon* 4 (8): e00715.

Gutirrez, Margareth, Victor Cantillo, Julian Arellana, and Juan de Dios Ortuzar. 2020. "Estimating Bicycle Demand in an Aggressive Environment." *International Journal of Sustainable Transportation*, 1–14.

Guzman, Luis A, Julian Arellana, and Vilma Alvarez. 2020. "Confronting Congestion in Urban Areas: Developing Sustainable Mobility Plans for Public and Private Organizations in Bogotá." *Transportation Research Part A: Policy and Practice* 134: 321–35.

Gwilliam, Ken. 2003. "Urban Transport in Developing Countries." *Transport Reviews* 23 (2): 197–216.

Gwilliam, Kenneth. 2013. "Cities on the Move–Ten Years After." *Research in Transportation Economics* 40 (1): 3–18.

Hallal, Pedro C, Rodrigo S Reis, Diana C Parra, Christine Hoehner, Ross C Brownson, and Eduardo J Simões. 2010. "Association Between Perceived Environmental Attributes and Physical Activity Among Adults in Recife, Brazil." *Journal of Physical Activity and Health* 7 (s2): S213–S222.

Hammadi, Saad. 2016. "Rajshahi: The City That Took on Air Pollution and Won." *The Guardian*, June. https://www.theguardian.com/world/2016/jun/17/rajshahi-bangladesh-city-air-pollution-won.

Haque, Ashraful. 2014. "Transport Situation in Rajshahi." Presenetd at the United Nations Economic; Social Commission for Asia; the Pacific (UN ESCAP)".

Hatamzadeh, Yaser, Meeghat Habibian, and Ali Khodaii. 2017. "Walking and Jobs: A Comparative Analysis to Explore Factors Influencing Flexible and Fixed Schedule Workers, a Case Study of Rasht, Iran." *Sustainable Cities and Society* 31: 74–82.

Hossain, Iqbal. 2018. "Women Labour Force in Bangladesh: Key Facts and Trends." *The Financial Express.* https://today.thefinancialexpress.com.bd/26th-anniversary-issue-3/women-labour-force-in-bangladesh-key-facts-and-trends-1544443424.

Huertas, Jorge A, Alejandro Palacio, Marcelo Botero, Germán A Carvajal, Thomas van Laake, Diana Higuera-Mendieta, Sergio A Cabrales, Luis A Guzman, Olga L Sarmiento, and Andrés L Medaglia. 2020. "Level of Traffic Stress-Based Classification: A Clustering Approach for Bogotá, Colombia." *Transportation Research Part D: Transport and Environment* 85: 102420.

Jamal, Shaila., and Mohiuddin Hossain. 2020. "Active Transportation Indicators and Establishing Baseline in a Developing Country Context: A Study of Rajshahi, Bangladesh." Journal Article. *Growth and Change - A Journal of Urban and Regional Policy.* https://doi.org/DOI: 10.1111/grow.12420.

Jäppinen, Sakari, Tuuli Toivonen, and Maria Salonen. 2013. "Modelling the Potential Effect of Shared Bicycles on Public Transport Travel Times in Greater Helsinki: An Open Data Approach." Journal Article. *Applied Geography* 43: 13–24.

Jia, Yingnan, Tricia Usagawa, and Hua Fu. 2014. "The Association Between Walking and Perceived Environment in Chinese Community Residents: A Cross-Sectional Study." *PloS One* 9 (2): e90078.

Khan, Maliha. 2017. "Rajshahi: A Model for Tackling Ambient Air Pollution in Our Cities." *The Daily Star*, June. https://www.thedailystar.net/star-weekend/rajshahi-model-tackling-ambient-air-pollution-our-cities-1414174.

Korzhenevych, A., and M. Jain. 2018. "Area- and Gender-Based Commuting Differentials in India's Largest Urban-Rural Region." Journal Article. *Transportation Research Part D-Transport and Environment* 63: 733–46. https://doi.org/10.1016/j.trd.2018.07.013.

Krueger, R., A. Vij, and T. H. Rashidi. 2018. "Normative Beliefs and Modality Styles: A Latent Class and Latent Variable Model of Travel Behaviour." Journal Article. *Transportation* 45 (3): 789–825. https://doi.org/10.1007/s11116-016-9751-1.

Kuranami, Chiaki, and Bruce P Winston. 1994. "Factors Influencing Ownership and Use of Nonmotorized Vehicles in Asian Cities." *Transportation Research Record*, no. 1441.

Landman, Karina. 2012. "Reconsidering Crime and Urban Fortification in South Africa." Book Section. In *The Urban Fabric of Crime and Fear*, edited by Vania Ceccato, 239–64. Dordrecht: Springer Netherlands. https://doi.org/10.1007/978-94-007-4210-9_10.

Larranaga, Ana Margarita, Julián Arellana, Luis Ignacio Rizzi, Orlando Strambi, and Helena Beatriz Bettella Cybis. 2019. "Using Best–Worst Scaling to Identify Barriers to Walkability: A Study of Porto Alegre, Brazil." *Transportation* 46 (6): 2347–79.

Larrañaga, Ana Margarita, Luis Ignacio Rizzi, Julian Arellana, Orlando Strambi, and Helena Beatriz Bettella Cybis. 2016. "The Influence of Built Environment and Travel Attitudes on Walking: A Case Study of Porto Alegre, Brazil." *International Journal of Sustainable Transportation* 10 (4): 332–42.

Laverty, Anthony A, Jennifer S Mindell, Elizabeth A Webb, and Christopher Millett. 2013. "Active Travel to Work and Cardiovascular Risk Factors in the United Kingdom." *American Journal of Preventive Medicine* 45 (3): 282–88.

Lavery, T. A., A. Paez, and P. S. Kanaroglou. 2013. "Driving Out of Choices: An Investigation of Transport Modality in a University Sample." Journal Article. *Transportation Research Part A-Policy and Practice* 57: 37–46. https:

//doi.org/10.1016/j.tra.2013.09.010.

Lemanski, C. 2012. "Everyday Human (in)security: Rescaling for the Southern City." Journal Article. *Security Dialogue* 43 (1): 61–78. https://doi.org/10.1177/0967010611430435.

Li, Jun. 2011. "Decoupling Urban Transport from Ghg Emissions in Indian Cities-a Critical Review and Perspectives." Journal Article. *Energy Policy* 39 (6): 3503–14. https://doi.org/10.1016/j.enpol.2011.03.049.

Liao, Yung, I Wang, Hsiu-Hua Hsu, Shao-Hsi Chang, and others. 2015. "Perceived Environmental and Personal Factors Associated with Walking and Cycling for Transportation in Taiwanese Adults." *International Journal of Environmental Research and Public Health* 12 (2): 2105–19.

Loo, L. Y. L., J. Corcoran, D. Mateo-Babiano, and R. Zahnow. 2015. "Transport Mode Choice in South East Asia: Investigating the Relationship Between Transport Users' Perception and Travel Behaviour in Johor Bahru, Malaysia." Journal Article. *Journal of Transport Geography* 46: 99–111. https://doi.org/10.1016/j.jtrangeo.2015.06.011.

Mackenbach, Joreintje, Edward Randal, Pengjun Zhao, and Philippa Howden-Chapman. 2016. "The Influence of Urban Land-Use and Public Transport Facilities on Active Commuting in Wellington, New Zealand: Active Transport Forecasting Using the Wilute Model." *Sustainability* 8 (3): 242.

Martin, A., Y. Goryakin, and M. Suhrcke. 2014. "Does Active Commuting Improve Psychological Wellbeing? Longitudinal Evidence from Eighteen Waves of the British Household Panel Survey." Journal Article. *Preventive Medicine* 69: 296–303. https://doi.org/10.1016/j.ypmed.2014.08.023.

Martín, Belén, and Antonio Páez. 2019. "Individual and Geographic Variations in the Propensity to Travel by Active Modes in Vitoria-Gasteiz, Spain." Journal Article. *Journal of Transport Geography* 76: 103–13. https:

//doi.org/https://doi.org/10.1016/j.jtrangeo.2019.03.005.

Miller, Harvey J. 2011. "Collaborative Mobility: Using Geographic Information Science to Cultivate Cooperative Transportation Systems." Journal Article. *Procedia - Social and Behavioral Sciences* 21 (0): 24–28. https://doi.org/http://dx.doi.org/10.1016/j.sbspro.2011.07.005.

Miratrix, Luke. 2018. *Textreg: N-Gram Text Regression, Aka Concise Comparative Summarization*. https://CRAN.R-project.org/package=textreg.

Mitra, Suman Kumar. 2016. "Land Use, Land Value, and Transportation: Essays on Accessibility, Carless Households, and Long-Distance Travel." PhD thesis, University of California, Irvine.

Molina-García, Javier, James F Sallis, and Isabel Castillo. 2014. "Active Commuting and Sociodemographic Factors Among University Students in Spain." *Journal of Physical Activity and Health* 11 (2): 359–63.

Moniruzzaman, M., and A. Paez. 2012. "A Model-Based Approach to Select Case Sites for Walkability Audits." Journal Article. *Health & Place* 18 (6): 1323–34. https://doi.org/10.1016/j.healthplace.2012.09.013.

———. 2016. "An Investigation of the Attributes of Walkable Environments from the Perspective of Seniors in Montreal." Journal Article. *Journal of Transport Geography* 51: 85–96. https://doi.org/10.1016/j.jtrangeo.2015.12.001.

Moniruzzaman, M., A. Paez, and C. Morency. 2014. "Compliance Potential Mapping: A Tool to Assess Potential Contributions of Walking Towards Physical Activity Guidelines." Journal Article. *BMC Public Health* 14: 11. https://doi.org/10.1186/1471-2458-14-511.

Munter, Jeroen SL de, Charles Agyemang, Lizzy M Brewster, Karien Stronks, and Irene GM van Valkengoed. 2012. "The Association of Leisure-Time Physical Activity and Active Commuting with Measures of Socioeconomic Position in a Multiethnic Population Living in the Netherlands: Results from the Cross-

Sectional Sunset Study." *BMC Public Health* 12 (1): 815.

Nazelle, A. de, M. J. Nieuwenhuijsen, J. M. Anto, M. Brauer, D. Briggs, C. Braun-Fahrlander, N. Cavill, et al. 2011. "Improving Health Through Policies That Promote Active Travel: A Review of Evidence to Support Integrated Health Impact Assessment." Journal Article. *Environment International* 37 (4): 766–77. https://doi.org/10.1016/j.envint.2011.02.003.

Nobis, C. 2007. "Multimodality - Facets and Causes of Sustainable Mobility Behavior." Journal Article. *Transportation Research Record*, no. 2010: 37–46. ISI:000252769600005.

Oliva, Ignacio, Patricia Galilea, and Ricardo Hurtubia. 2018. "Identifying Cycling-Inducing Neighborhoods: A Latent Class Approach." *International Journal of Sustainable Transportation* 12 (10): 701–13.

Oyeyemi, Adewale L, Babatunde O Adegoke, James F Sallis, Adetoyeje Y Oyeyemi, and Ilse De Bourdeaudhuij. 2012. "Perceived Crime and Traffic Safety Is Related to Physical Activity Among Adults in Nigeria." *BMC Public Health* 12 (1): 294.

Paez, A. 2013. "Mapping Travelers' Attitudes: Does Space Matter?" Journal Article. *Journal of Transport Geography* 26: 117–25. https://doi.org/10.1016/j.jtrangeo.2012.09.002.

Parra, Diana C, Christine M Hoehner, Pedro C Hallal, Isabela C Ribeiro, Rodrigo Reis, Ross C Brownson, Michael Pratt, and Eduardo J Simoes. 2011. "Perceived Environmental Correlates of Physical Activity for Leisure and Transportation in Curitiba, Brazil." *Preventive Medicine* 52 (3-4): 234–38.

Peterborough City and County. 2014. "Active Transport and Health Indicators Report." http://peterboroughmoves.com/wp-content/uploads/2015/05/IndicatorsReport_Final_Web.pdf.

Pojani, Dorina, and Dominic Stead. 2015. "Sustainable Urban Transport in the Developing World: Beyond Megacities." *Sustainability* 7 (6): 7784–7805.

Poushter, Jacob. 2015. "Car, Bike or Motorcycle? Depends on Where You Live." *Pew Research Center*. Pew Research Center. https://www.pewresearch.org/fact-tank/2015/04/16/car-bike-or-motorcycle-depends-on-where-you-live/.

Power and Participation Research Centre. 2016. "Bangladesh 2016: Politics, Governance and Middle Income Aspirations: Realities and Challenges: An Empirical Study." https://www.undp.org/content/dam/bangladesh/docs/Publications/Pub2016/policy%20brief.pdf.

Public Health Agency of Canada. 2011. "Fast Facts About Canada's Neighborhoods and Physical Activity. Data Compiled from the 2011 Canadian Community Health Survey Rapid Response Module on Neighborhood Environments." https://www.canada.ca/content/dam/phac-aspc/migration/phac-aspc/hp-ps/hl-mvs/assets/pdf/fast-facts-faits-rapidesV2-eng.pdf.

Pucher, John, Ralph Buehler, Dafna Merom, and Adrian Bauman. 2011. "Walking and Cycling in the United States, 2001–2009: Evidence from the National Household Travel Surveys." *American Journal of Public Health* 101 (S1): S310–S317.

Rahul, TM, and Ashish Verma. 2013. "Economic Impact of Non-Motorized Transportation in Indian Cities." *Research in Transportation Economics* 38 (1): 22–34.

Rosas-Satizábal, Daniel, and Alvaro Rodriguez-Valencia. 2019. "Factors and Policies Explaining the Emergence of the Bicycle Commuter in Bogotá." *Case Studies on Transport Policy* 7 (1): 138–49.

Rossetti, Tomás, Verónica Saud, and Ricardo Hurtubia. 2019. "I Want to Ride It Where I Like: Measuring Design Preferences in Cycling Infrastructure." *Transportation*, 1–22.

Sallis, James F, Abby C King, John R Sirard, and Cheryl L Albright. 2007.

"Perceived Environmental Predictors of Physical Activity over 6 Months in Adults: Activity Counseling Trial." *Health Psychology* 26 (6): 701.

Sá, Thiago Hérick de, Rafael Henrique Moraes Pereira, Ana Clara Duran, and Carlos Augusto Monteiro. 2016. "Socioeconomic and Regional Differences in Active Transportation in Brazil." *Revista de Saude Publica* 50: 37.

Sá, Thiago Hérick, Ana Clara Duran, Marko Tainio, Carlos Augusto Monteiro, and James Woodcock. 2016. "Cycling in São Paulo, Brazil (1997–2012): Correlates, Time Trends and Health Consequences." *Preventive Medicine Reports* 4: 540–45.

Schwendinger, Florian, and Kurt Hornik. 2019. *Pandocfilters: Pandoc Filters for R.* https://CRAN.R-project.org/package=pandocfilters.

Silva Bandeira, Alexsandra da, Kelly Samara da Silva, Giovâni Firpo Del Duca, Geyson Ricardo Zilch, Elusa Santina Antunes de Oliveira, Mauro Virgílio Gomes de Barros, and Markus Vinicius Nahas. 2017. "Factors Associated with Bicycle Use for Commuting and for Leisure Among Brazilian Workers." *Sport Sciences for Health* 13 (1): 63–68.

Srinivasan, Karthik K, Gautam N Pradhan, and G Maheswara Naidu. 2007. "Commute Mode Choice in a Developing Country: Role of Subjective Factors and Variations in Responsiveness Across Captive, Semicaptive, and Choice Segments." *Transportation Research Record* 2038 (1): 53–61.

Tainio, M., A. J. de Nazelle, T. Gotschi, S. Kahlmeier, D. Rojas-Rueda, M. J. Nieuwenhuijsen, T. H. de Sa, P. Kelly, and J. Woodcock. 2016. "Can Air Pollution Negate the Health Benefits of Cycling and Walking?" Journal Article. *Preventive Medicine* 87: 233–36. https://doi.org/10.1016/j.ypmed.2016.02.002.

Train, K. 2009. *Discrete Choice Methods with Simulation.* Book. 2nd Edition. Cambridge: Cambridge University Press.

Van Acker, V., P. L. Mokhtarian, and F. Witlox. 2011. "Going Soft: On

How Subjective Variables Explain Modal Choices for Leisure Travel." Journal Article. *European Journal of Transport and Infrastructure Research* 11 (2): 115–46. %3CGo%20to%20ISI%3E://WOS:000289343300002.

Van Acker, V., B. Van Wee, and F. Witlox. 2010. "When Transport Geography Meets Social Psychology: Toward a Conceptual Model of Travel Behaviour." Journal Article. *Transport Reviews* 30 (2): 219–40. ISI:000274540400004.

Van Cauwenberg, Jelle, Peter Clarys, Ilse De Bourdeaudhuij, Veerle Van Holle, Dominique Verté, Nico De Witte, Liesbeth De Donder, Tine Buffel, Sarah Dury, and Benedicte Deforche. 2012. "Physical Environmental Factors Related to Walking and Cycling in Older Adults: The Belgian Aging Studies." *BMC Public Health* 12 (1): 142.

Van Cauwenberg, Jelle, Veerle Van Holle, Dorien Simons, Riet Deridder, Peter Clarys, Liesbet Goubert, Jack Nasar, Jo Salmon, Ilse De Bourdeaudhuij, and Benedicte Deforche. 2012. "Environmental Factors Influencing Older Adults' Walking for Transportation: A Study Using Walk-Along Interviews." *International Journal of Behavioral Nutrition and Physical Activity* 9 (1): 85.

Venables, W. N., and B. D. Ripley. 2002. *Modern Applied Statistics with S*. Fourth. New York: Springer. http://www.stats.ox.ac.uk/pub/MASS4.

Vij, A., A. Carrel, and J. L. Walker. 2013. "Incorporating the Influence of Latent Modal Preferences on Travel Mode Choice Behavior." Journal Article. *Transportation Research Part a-Policy and Practice* 54: 164–78. https://doi.org/10.1016/j.tra.2013.07.008.

Weber Corseuil, Maruí, Pedro Curi Hallal, Herton Xavier Corseuil, Ione Jayce Ceola Schneider, and Eleonora d'Orsi. 2012. "Safety from Crime and Physical Activity Among Older Adults: A Population-Based Study in Brazil." *Journal of Environmental and Public Health* 2012.

Whalen, Kate E, Antonio Páez, and Juan A Carrasco. 2013. "Mode Choice of University Students Commuting to School and the Role of Active Travel." *Journal of Transport Geography* 31: 132–42.

Wickham, Hadley. 2007. "Reshaping Data with the reshape Package." *Journal of Statistical Software* 21 (12): 1–20. http://www.jstatsoft.org/v21/i12/.

Wickham, Hadley, Mara Averick, Jennifer Bryan, Winston Chang, Lucy D'Agostino McGowan, Romain François, Garrett Grolemund, et al. 2019. "Welcome to the tidyverse." *Journal of Open Source Software* 4 (43): 1686. https://doi.org/10.21105/joss.01686.

Wickham, Hadley, and Jennifer Bryan. 2019. *Readxl: Read Excel Files*. https://CRAN.R-project.org/package=readxl.

Xie, Yihui. 2014. "Knitr: A Comprehensive Tool for Reproducible Research in R." In *Implementing Reproducible Computational Research*, edited by Victoria Stodden, Friedrich Leisch, and Roger D. Peng. Chapman; Hall/CRC. http://www.crcpress.com/product/isbn/9781466561595.

———. 2015. *Dynamic Documents with R and Knitr*. 2nd ed. Boca Raton, Florida: Chapman; Hall/CRC. https://yihui.org/knitr/.

———. 2019. "TinyTeX: A Lightweight, Cross-Platform, and Easy-to-Maintain Latex Distribution Based on Tex Live." *TUGboat*, no. 1: 30–32. http://tug.org/TUGboat/Contents/contents40-1.html.

———. 2020. *Tinytex: Helper Functions to Install and Maintain 'Tex Live', and Compile 'Latex' Documents*. https://github.com/yihui/tinytex.

Ye, Runing, and Helena Titheridge. 2017. "Satisfaction with the Commute: The Role of Travel Mode Choice, Built Environment and Attitudes." *Transportation Research Part D: Transport and Environment* 52: 535–47.

Zaluar, Alba. 2012. "Turf War in Rio de Janeiro: Youth, Drug Traffic, Guns and Hyper-Masculinity." Book Section. In *The Urban Fabric of Crime and Fear*, edited by Vania Ceccato, 217–37. Dordrecht: Springer Netherlands.

https://doi.org/10.1007/978-94-007-4210-9_9.

Zhao, P. J., and S. X. Li. 2016. "Restraining Transport Inequality in Growing Cities: Can Spatial Planning Play a Role?" Journal Article. *International Journal of Sustainable Transportation* 10 (10): 947–59. https://doi.org/10.1080/15568318.2016.1191693.

Zhu, Hao. 2019. *KableExtra: Construct Complex Table with 'Kable' and Pipe Syntax*. https://CRAN.R-project.org/package=kableExtra.