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DOI:

[10.1016/j.jtrangeo.2018.04.004](https://doi.org/10.1016/j.jtrangeo.2018.04.004)

Document Version

Accepted author manuscript

[Link to publication record in Manchester Research Explorer](#)

Citation for published version (APA):

Acheampong, R. A., & Siiba, A. (2018). Examining the determinants of utility bicycling using a socio-ecological framework: An exploratory study of the Tamale Metropolis in Northern Ghana. *Journal of Transport Geography*, 69, 1-10. <https://doi.org/10.1016/j.jtrangeo.2018.04.004>

Published in:

Journal of Transport Geography

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Examining the determinants of utility bicycling using a socio-ecological framework: An exploratory study of the Tamale Metropolis in Northern Ghana

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This is the authors' version of the original article published in *Journal of Transport Geography*

Access original article at: <https://doi.org/10.1016/j.jtrangeo.2018.04.004>

Received 10 May 2017; Received in revised form 22 March 2018; Accepted 3 April 2018

Cite as: Acheampong, R. A., & Siiba, A. (2018). Examining the determinants of utility bicycling using a socio-ecological framework: An exploratory study of the Tamale Metropolis in Northern Ghana. *Journal of Transport Geography*, 69, 1-10.

Abstract

This paper examines the determinants of utility bicycling through a cross-sectional study in Tamale, a metropolis with a long history of an embedded cycling culture in Ghana, West Africa. Using a socio-ecological framework, we model the extent to which individual-level characteristics, social environment factors and perceptions of physical environment factors at the neighbourhood and metropolitan scales influence choice of the bicycle as the main transport mode. An exploratory factor analysis distilled the indicators of the latent constructs of the socio-ecological framework into factors, which reflect physical environment challenges and opportunities perceived at the neighbourhood and metropolitan scales; influence of significant others; perceived status symbol of the bike; and perceived commuting benefits of bicycling. A binary logistic regression analysis of the determinants of utility cycling shows that while overall, bicycle ownership is an important determinant of cycling, between the genders, males are more likely to bicycle than females. Also, cyclists are more likely to be non-tertiary educated individuals. Whereas ‘perceived neighbourhood-scale challenges’ decrease the odds of cycling, ‘perceived neighbourhood-scale opportunities’, which reflect the availability of bicycle lanes, alternative roads and traffic control measures increase the likelihood of cycling among the study respondents. An interaction term between neighbourhood-scale physical environment opportunities and challenges, however, correlates negatively with cycling, suggesting that overall the metropolitan physical environment is not ideal for cycling. The study points to a huge potential for cycling in the metropolis and provides an empirical basis for interventions needed to remove barriers to bicycle commuting.

Key Words: *Bicycle commuting; travel behaviour; sustainable; transportation; non-motorised transport; Ghana*

1. Introduction

Reducing motorised transport mode use and the attendant negative impacts on the environment and human health is crucial in the transitions towards sustainable urban futures. It is now recognized that promoting the adoption of active transport modes such as bicycling and walking constitutes one of the effective pathways towards creating environmentally friendly and healthier cities (Handy and Xing, 2011; Parkin et al., 2007).

Bicycle ridership is considered environmentally sustainable compared to motorised alternatives because of the low energy consumption and the absence of direct emission of pollutants such as green-house gases and noise (Gatersleben and Appleton, 2007). Moreover, the bicycle can offer several commuting benefits including affordability, reliability and speed, making it a suitable mode of transport for many urban and sub-urban trips (Bonham and Koth, 2010; Heinen et al., 2010; Shaheen et al., 2010). Research has also demonstrated that bicycling on a regular basis could improve personal health by reducing sedentary lifestyles in the population (Haskell, 2004; Titze et al., 2008; Van Dyck et al., 2013).

Despite the many known benefits of utility bicycling, bicycle mode share in most cities across the globe is still considerably low (Gatersleben and Appleton, 2007; Heesch et al., 2014). In the context of African cities for example, the low adoption rate has been attributed to the negative image of cycling in the population, which many perceive as inferior alternative to the car; the lack of adequate infrastructure for non-motorised transportation; and the general failure of transport policy to incorporate cycling into the urban transport mix (Olvera et al., 2008; Acheampong, 2016; Brussel and Zuidgeest, 2012; Nkurunziza et al., 2012).

Notwithstanding the negative perceptions of cycling in the population and the general lack of interest in harnessing the potential of the bicycle, particularly in cities in developing countries, there are rare examples of bicycling culture to be found in these contexts. In Ghana, for example, the northern part of the country has long been known for its cycling culture, evidenced by the relatively high levels of bicycle ownership and use. It is estimated that nearly 11% of school trips in the Northern Region of Ghana are undertaken using the bicycle (Ghana Statistical Service, 2014). Moreover, while about 20% of the population across Ghana owned a bicycle, in the savannah regions (i.e. Northern, Upper East and Upper West regions), the level of ownership was found to be significantly higher at 63% according to the Ghana Living

Standards Survey, Round 6, 2014¹ (Ghana Statistical Service, 2014). Although the forgoing statistics referred specifically to rural areas in the savannah regions and do not provide any information about bicycle use beyond ownership, they lend credence to the embedded cycling culture in these parts of the country. It therefore, makes interesting studying in this context, the underlying motivations for cycling among the population who do so and the barriers to cycling among those who do not.

The objective of this study, therefore, is to understand the determinants of utility bicycling in northern Ghana from the perspective of a socio-ecological model. To this end, we examine the influence of personal characteristics, perceived control and beliefs, attitudes and socio-environmental factors on adults' decision to bicycle for transportation in the Tamale metropolis, the biggest urban centre in the Northern part of Ghana. We aim, through understanding the behavioural influences of cycling in this unique case of cycling culture in Ghana, to provide empirical basis for cycling promotion interventions in the study area and possibly across other cities in the country.

The rest of the paper follows in four main sections. We first present the socio-ecological model for studying bicycling behaviour adopted in this study. Next, a brief discussion of the urban transportation situation in Ghana is presented to set the context for this study. The methodology adopted for this study is discussed focusing on the design of a questionnaire to measure the components of the socio-ecological model, sampling techniques, data collection and the method of analysis employed. In the fourth section, results of the analysis of the determinants of bicycling are presented followed by a discussion of the main findings of the study and their policy implications in the concluding section.

2. Socio-ecological models and bicycling behaviour

Traditionally, utility theory, which posits that people make their travel decisions by evaluating factors including out-of-pocket costs, travel time and personal convenience has underpinned analyses of travel behaviour (Ortúzar and Willumsen, 2011; Jain and Lyons, 2008; Acheampong and Silva, 2015). Increasingly, the role of more fundamental socio-psychological and ecological factors in interacting with personal attributes to influence travel choices has gained recognition, particularly in active transport (i.e. walking and bicycling) research (see e.g. Ghekiere et al., 2017; Sigurdardottir et al., 2013). This development is premised on the

¹ Data is based on a sample population of 16,766 across Ghana interviewed as part of the Ghana Living Standards Survey, Round 6.

recognition that physical infrastructure-related investments as well as knowledge of beliefs, perceptions, attitudes and the influence of significant others (i.e. other persons who could have an influence on one's behaviour e.g. peers and parents) are crucial to successfully getting more people to adopt the bike as the main mode of transportation (Moudon et al., 2005; Acheampong, 2017; Sigurdardottir et al. 2013).

In a bid to better understand the behavioural influences of bicycling, researchers have deployed cognitive models such as the Theory of Planned Behaviour (TPB) (Ajzen, 1985, 1991). TPB-based research (see e.g. Sun et al., 2015; Bamberg et al., 2011; Quine, et al., 1998; Chowdhury et al., 2013) examines the motivations and barriers to behaviour as a function of individuals' attitude towards the behaviour (e.g. bicycling), perceived control and subjective norm. Notwithstanding the usefulness of cognitive approaches such as TPB in understanding behaviour under volitional control, the emphasis on aggregating the factors influencing behaviour into the individual with little representation of other relevant external factors has come under criticism (see e.g. Handy and Xing, 2011; Alfonzo, 2005).

Against the background of the weaknesses of the individually focused cognitive theories and models, current research has sought to integrate individual-level factors with external environmental factors to understand cycling behavior. Given that cycling is not only a means of travel but also a form of physical activity, it has been argued that the socio-ecological model (McLeroy et al., 1988) widely used in physical activity research in public health could provide a robust framework to conceptualize and understand cycling behavior (Sigurdardottir et al., 2013; Handy and Xing, 2011).

The social-ecology concept refers to the interrelationships between organisms (e.g. human beings) and their environments (i.e. social, physical and natural) (Sallis, et al., 2008). The socio-ecological model posits that behavior is influenced by intrapersonal, interpersonal, institutional (i.e. formal and informal behavioural rules), community, and public policy factors (McLeroy et al., 1988). In other words, it recognizes that attributes of the individual as well as social, physical, natural and policy environments interact to influence behavior (McLeroy et al., 1988; Badland et al., 2013; Sallis et al., 2008; Elder, et al., 2007). The socio-ecological model therefore integrates concepts and models from a broad range of disciplines.

At the level of the individual and within the context of cycling behaviour, a socio-ecological model considers intrapersonal factors including socio-demographics (e.g. age, gender, education, income; employment status), attitudes, perceived control and beliefs, and bicycle

ownership in examining the determinants of cycling. Generally, age influences physical ability, hence previous research has concluded that cycling levels decline as people age (see e.g. Moudon et al. 2005; Dill and Voros, 2007). Previous studies have also shown that being female decreased the likelihood of cycling (Wardman et al. 2007; Parkin et al., 2008) or decreased intended adoption of utility cycling (Acheampong, 2017). The extant literature has arrived at mixed conclusions with respect to the influence of income on bicycle commute. While some studies have found a positive association between income and bicycle commuting (e.g. Shafizadeh and Niemeier 1997), others have reported negative (e.g. Plaut, 2005; Parkin et al., 2008) or no effect of income on bicycle commuting (Stinson and Bhat, 2004).

In addition, attitudes, perceived control and self-efficacy, constructs originally captured in Ajzen's (1985, 1991) TPB as determinants of behaviour under volitional control have also been integrated into socio-ecological models (see e.g. Sigurdardottir et al., 2013). An individual's attitude reflects his or her expectations of outcomes of an activity and the personal values attached to them (Sutton, et al., 2003) as well as specific opinions, intentions, affections, and beliefs (Handy and Xing, 2011; Heinen et al., 2011). It is hypothesised that where the expected outcomes of cycling to the individual are positive, they are more likely to adopt utilitarian cycling. Moreover, perceived control and self-efficacy—a person's evaluation of the possibility of performing certain behaviour and judgments of how well she/he can execute courses of action required to deal with prospective situations (Ajzen, 1991; Armitage and Connor, 2001)—determine whether they bicycle or not. Previous researchers have established that individuals who perceive more barriers to commuting by bicycle are less likely to cycle, and that in general, cyclists perceive more possibilities for cycling than non-cyclists (Gatersleben and Appleton 2007). Nonetheless, in some other cases, negative perceptions of cycling outcomes have been associated with physical inability and poor health conditions (Handy and Xing, 2011).

Within the framework of the socio-ecological model, interpersonal and community factors on behaviour reflect in part, the influence of the wider social environment on an individual's behaviour (McLeroy et al., 1988). These comprise factors such as social norms, influence of significant others such as family members, social networks, and behaviours considered normal or appropriate, which tend to regulate behaviour by acting as informal social controls (McLeroy et al., 1988). For instance, de Geus et al. (2008) show that having relatives who bicycle and give social support through cycling to their relatives and friends increases the likelihood that one would cycle for transport. In a study of adolescents' intentions to commute by car or

bicycle as adults, Sigurdardottir et al., (2013) show that higher subjective norms of car ownership (i.e. perceived social pressure to obtain a driving license and to own a car) correlated negatively with intentions to cycle to work. Similarly, a study of adults' intended adoption of cycling as work travel mode in Kumasi, Ghana revealed a negative association between subjective norms, and attitudes and perceived control (Acheampong, 2017). The findings of this study suggest that beliefs about the prestige of cycling relative to other modes, and approval of society and significant others of cycling, influenced perception of control and confidence as well as attitude with respect to cycling.

Besides the external social factors, attributes of the physical/built environment, which could be considered as forming part of the geographical context under community factors in McLeroy et al's., (1988) socio-ecological model, have also been reported to influence bicycling. Various research works have demonstrated the effect of built environment attributes including land use density and diversity, street connectivity and distance between trip origins and destinations on utility cycling. Denser residential neighbourhoods (Pucher and Buehler, 2006) and mixed land uses (Cervero and Duncan, 2003; Beenackers et al., 2012) reduce travel distances and increase bicycle mode share while larger traffic volumes (Parkin et al. 2008) and increases in trip distance (Dickinson et al., 2003; Timperio et al., 2006; Parkin et al., 2008) are negatively associated with bicycling. Moreover, natural factors such as landscape, weather and topography (Timperio et al., 2006) may determine whether a person chooses to cycle or not.

Finally, policy interventions such as bicycle sharing schemes, favourable land use policies for active transport and health promotion strategies could shape perceptions and attitudes towards cycling and create an urban environment that prioritizes cyclists over motorists and enhance cyclist's safety (Handy and Xing, 2011; Shaheen et al., 2010; Garrard and Rose, 2008).

Depending on the nature and field of research as well as the context, different combinations of the relevant socio-ecological model constructs outlined above could be deployed. Nonetheless, any form of socio-ecological model revolves around the fundamental principle that an individual's behaviour is influenced by multiple factors, and that behaviour is a function of the interaction between people and their social, physical, natural and policy environments (Jamner and Stokols, 2000; McLeroy et al., 1988). The nature and magnitude of influence of these factors on travel choices, including cycling depend on the context of investigation.

3. The Context: Urban transportation in Ghana

In Ghana, motorised transport (i.e. private cars and mini-buses known locally as *Trotro*) accounts for more than 90% of all passenger trips in urban areas (Integrated Transport Plan for Ghana, 2010). Car ownership and use in the country's major cities, including Accra and Kumasi, in particular, has been on the rise in recent years (Adarkwa and Poku-Boansi, 2011). It is estimated that private vehicle to population ratio increased from 50 vehicles per 1,000 population in 2010 to about 70 vehicles per 1,000 population in 2015 (Ministry of Transport, 2016). The evidence suggests that the increasing levels of motorization is as a result of few individuals, probably the growing middle-class, owning cars in the country (see e.g. Obeng-Odoom, 2010). Consequently, congestion in central areas, long commuting times, journey delays and pollution (air and noise) typify the urban transport situation in the country (Armah et al., 2010; Obeng-Odoom, 2010). It is estimated that vehicular emissions alone are responsible for 70% of total greenhouse gas emissions in Ghana (World Bank, 2009).

On the contrary, very few people use non-motorised forms of transportation, particularly cycling in the country. In the urban centres of the south, less than three percent of urban dwellers use non-motorised transport (i.e. walking and cycling) (Integrated Transport Plan for Ghana, 2010). In the three northern regions of Ghana (i.e. Northern, Upper East and Upper West regions), however, the bicycle is used extensively in both urban and rural areas as the main mode of transportation (UN-HABITAT, 2009; Ghana Statistical Service, 2014). Specifically, in the rural areas of these regions, an estimated 63% of the population owned bicycles, with about 11% of all school trips being undertaken by this mode of transportation (Ghana Statistical Service, 2014).

The underlying reasons for the embedded cycling culture in the northern regions are not well known. That notwithstanding that, it is possible that the scattered patterns of settlements, the generally flat, mostly arid landscape as well as the high levels of poverty in the north relative to the southern parts of Ghana, have positioned the bicycle as an affordable, yet a relatively faster mobility option that enables the population to overcome distance over relatively shorter period of time as opposed to if they were to walk. In addition to the scattered pattern of settlements, the Tamale metropolis itself exhibits closely the mono-centric urban spatial structure where major activities and functional uses are concentrated in the historical-core neighbourhoods. Within this context, and especially in instances where vehicles are not

available or transport fares are beyond the means of the population, the bicycle could be a substitute mode of transport for daily activities.

While perceptions of cycling as an inferior mode of transport are widespread in the population (see e.g. Acheampong, 2017), policy responses towards harnessing the potential of cycling as a mainstream travel mode has not been forthcoming. The Ghana National Transport Policy, formulated in 2008, set an ambitious target to increase the modal share of non-motorised travel by 10%, with the aim of increasing access to affordable mobility, promoting physical well-being and ensuring environmental quality (Government of Ghana, 2008). To-date, however, concrete actions to achieve this target are yet to be seen. Even in areas where bicycling has existed for several years, policy response in terms of infrastructure provision and cycling promotion programmes aimed at shifting attitudes and changing behaviours have been non-existent. Indeed, only a handful of research (see e.g. Acheampong, 2016; Acheampong, 2017) has paid attention to this almost neglected aspect of urban mobility, implying that the empirical evidence that could potentially inform cycling promotion interventions in Ghana are also limited. This paper, therefore, uses the Tamale metropolis as a case study to bridge the gap in our knowledge of the motivations and barriers to cycling in Ghana.

4. Methodology

4.1 Tamale Metropolis—the case study area

Tamale metropolis is the third largest metropolis in Ghana (after Accra and Kumasi) with an estimated population of 223,252 (Ghana Statistical Services, 2014). It is the biggest urban settlement in the northern savannah regions of Ghana and functions as the administrative capital of Northern Region, one of the 10 administrative regions in Ghana.

Taxi cabs, cycling, motorcycling and private cars are the main modes of transport in the metropolis. Taxi cabs account for about 25% of the daily travel mode share while travel by car accounts for only 10% (TaMA 2015). Combined trips by bicycles and motorcycles represent about one-third of the travel mode share in the city (TaMA 2015). While the bicycle has been the dominant mode of transportation over several years, in recent years, motorcycles have become ubiquitous, signalling a gradual transition from the pedal to the engine. Major road arterials in the metropolis have designated bicycle lanes, making it probably the most bike-friendly urban environment in Ghana. In addition, with an elevation between 150 meters and 180 meters above sea level, the topography is fairly flat with very few isolated hills, making it relatively easy for bicycling.

Despite cycling being one of the popular mode of travel by the population, only a handful of policy reports have mentioned the embedded bicycling culture in the metropolis compared to other urban centres in Ghana (UN-HABITAT, 2009; Government of Ghana, 2008). Thus, the Tamale metropolis provides a good case study to understand why people choose to ride the bicycle or otherwise and to provide empirically-grounded insight that could inform interventions aimed at achieving the 10% increase in non-motorised transport use (i.e. walking and bicycling) set by Ghana's National Transport Policy.

4.2. Questionnaire design

The study adopted a cross-sectional survey design to examine the factors influencing utility cycling among adults in the Tamale metropolis in Northern Ghana. Using the socio-ecological model, a structured questionnaire was designed to obtain self-reported information from adult participants on their personal characteristics; perceived control and beliefs; attitude; perceived influence of the social environment; perceived influence of the physical and natural environments; and policy factors related to bicycling. Under each of the components of the framework, a list of relevant factors hypothesised and or established in the literature to influence utility cycling (see. e.g. Heinen et al., 2010; Sigurdardottir et al. 2013) were identified and used to construct response items in the questionnaire.

Utility cycling was explained to the study respondents as cycling for daily activities including work and shopping, attending school, church/mosque and visiting friends and family but excluding cycling for recreational purposes. Self-reported cycling frequencies in the seven-day period (i.e. week) preceding the day of the interview were elicited by the survey. In addition, based on their self-reported cycling frequency, participants also selected one of four predetermined groups namely; (i) 'Frequent-cyclists'—those who cycled every day in the seven-day period; (ii) 'Occasional cyclists'—those who cycled at least once in the seven-day period; (iii) 'Past cyclists' those who cycled previously but have not done so over the past two years; and (iv) 'Non-cyclist'—those who have never cycled in their life. Information on when the participants first cycled, bicycle ownership and main mode of transport were also obtained. Data on *personal characteristics* including age, gender, levels of educational attainment, household income and car ownership were also elicited.

The *participants perceived control and beliefs* with respect to cycling were elicited using statements that sought to capture perceived self-efficacy—the ease or difficulty associated with cycling and the anticipated impediments and obstacles to cycling as perceived by the

respondents. The participants responded on a five-point Likert scale the extent to which they agreed or disagreed with statements on their perception of physical-fitness, control, confidence as well as their beliefs regarding the likelihood of being involved in accidents and whether they regarded cycling as a travel mode that could be used for important social events just like the car or motorcycle. The exact wording of the questionnaire items and descriptive analysis of the respondents' responses are provided later in section 5.

Moreover, *attitude* towards cycling was assessed using questionnaire items that captured the expectations of the outcomes of bicycling and the positive and negative values placed on these outcomes by the respondents. Attitudinal items, including the benefits of cycling in terms of health, travel speed, affordability and environmental-friendliness were evaluated on a five-point Likert scale.

The potential influence of the *social environment* on utility bicycling assessed the participants' perceptions of the general social views with respect to cycling. Specifically, the extent to which the approval of significant others including family relations (i.e. spouse, children etc.) would influence their decision to cycle were evaluated on a five-point Likert Scale. An item aimed at capturing the potential influence that seeing others cycle has on respondents' decision to cycle or not was also included under social environment.

Perceptions of relevant *physical environment factors* in relation to utility cycling were also elicited. The study examined the influence of neighbourhood and city-level characteristics on bicycle commuting, including traffic volume, traffic calming measures, alternative routes, dedicated cycling path, on-street parking and road surface conditions as perceived and experienced by the respondents. On a five-point Likert Scale, respondents indicated the extent to which they agreed or disagreed with the statements capturing these factors in relation to the routes they usually choose to their core activity locations, such as work, shopping and church/mosque attendance.

Given that there was no policy measure currently under way in relation to cycling in the metropolis, the extent to which current policy influenced cycling or otherwise could not be assessed from the point of view of the study respondents. Notwithstanding this, attributes of the physical environment including cycling lanes, street lighting and traffic calming measures, and secured parking for bicycling are all the product of previous policy interventions. Thus, the effect of policy to some extent is captured by these factors, although implicitly.

In addition to the Likert-scale questionnaire items, the respondents, in particular, those who identified themselves as cyclists provided further information as the interviews evolved regarding their daily encounters with motorists and the challenges they faced cycling in the metropolis. This information together with our field observations enhanced our understanding of the context and provided the basis to relate with and interpret the responses elicited.

4.3 Participant recruitment and interviews

A total of 455 adults were randomly sampled and interviewed. These individuals were selected from different residential locations in the case study metropolis with the aim of ensuring that the total sample reflected the diversity in the population. Consequently, 51% of the total sample interviewed resided in two of the metropolis' historical-core neighbourhoods namely; Moshie-Zongo (n = 101) and Sakasaka (n = 129). The remaining 17% (n = 79) and 32% (n= 146) of the total sample were recruited from the inner-suburban (i.e. Kalpohin) and outer-suburban (i.e. Lamashegu) neighbourhoods located some 2.5km and 4km from the main centre of the metropolis respectively. **Figure 1a** shows the location of the Tamale metropolis in Ghana and the neighbourhoods from which the study respondents were recruited and interviewed.

All interviews were conducted in the four residential neighbourhoods (**Figure 1b**) either at the place of residence of the respondents or by intercepting the respondents in the course of cycling to their respective destinations. In the latter cases, the home origins of the bicycle trips were recorded. The respondents were either interviewed face-to-face by trained field assistants or could opt to self-complete the questionnaire in the presence of a field assistant provided they could read and write. About 40% of the questionnaires were self-completed.

Figure 1a: Location of Tamale Metropolis in Ghana

Figure 1b: Location of the study neighbourhoods within the Tamale Metropolis

4.4 Statistical analyses

Two main inferential statistical analyses methods were used to examine the influence of the study variables on utility cycling. The socio-ecological model adopted in this study comprises

latent constructs, and several indicators were used to measure each construct. Consequently, Principal Component Analysis (PCA) was used to reduce the indicators of each construct to a reasonable number of factors. This is achieved by deriving linear correlations from combinations of the original variables and extracting new variables based on their associated eigenvalue (Jollif and Cadinna, 2016). Next, the rotated factor scores of the PCA together with the relevant socio-demographic variables were entered as explanatory variables in a binary logistic regression model. Utility cycling, the dependent variable was dichotomised as follows: (i) Cyclists, comprising all individuals who reported bicycling either frequently or occasionally and (ii) Non-cyclist, comprising the remaining two sub-categories of respondents labelled as 'Past cyclists' and 'Non-cyclists'. Thus, the logistic regression model was used to examine the relationships between the discrete categorical outcome variable (i.e. utility cycling) and the explanatory variables. In both the PCA and logistic regression models, the Five-point Likert scale responses to the questionnaire items were dichotomised: For example, 'strongly agree' and 'agree' were grouped as one category while 'neutral', 'disagree' and 'strongly disagree' were grouped as another category. Combining the PCA and logistic regression analysis allows us to examine the extent to which the various factors examined in the context of this study influence bicycle commuting, although the approach does not adequately account for measurement errors in latent variables included the analysis.

5. Results

5.1 Background characteristics of the respondents

Summary statistics on the characteristics of the study respondents is presented in **Table 1**. Males constituted 59% of the total sample of respondents. The study participants were aged between 18 and 65 years, with an average age of 30 years. Tertiary and non-tertiary educated individuals constituted 42% and 48% of the respondents respectively.

Out of the 455 respondents, 277, representing 61% were identified as cyclists. Among the cyclist-group, the survey found that about 64% of them started cycling in early childhood while the remaining 31% and five percent started cycling in their teenage and adult years respectively. About 39% of the respondents reported owning a bicycle. In terms of cycling frequency, the results show that on the average the respondents cycled three times in a period of seven days (i.e. one week). Majority of respondents in this group, bicycled mainly to agricultural, non-agricultural and school based activity destinations. Home-work distance was about 4.7km on the average while that of school was less than 2km. Besides these core activities, in a typical

day, they also bicycled to activities including going to the market/shops, attending mosque/church and visiting friends and relatives.

Table 1: Background information of the respondents (n = 455)

Cyclist-groups	Cyclists	61% (n=277)
	Non-cyclists	39% (n =178)
Stage of life first cycled (Cyclists only)	Early-childhood	64%
	Teen-ages	31%
	Adulthood (20+)	5%
Stage of life first cycled (Non-cyclists only)	Early-childhood	49%
	Teen-ages	30%
	Adulthood (20+)	2%
	Never-cycled	19%
Gender	Female	41%
	Male	59%
Age	Mean	30
	Std. Deviation	9.303
	Minimum	18
	Maximum	65
Marital status	Single	51%
	Married	49%
Education	Basic school	16%
	Senior-high/vocational	42%
	Tertiary	42%
Residential location	Historical-core	51%
	Inner-suburban	17%
	Outer-suburb	32%
Cycling frequency (per week)	Mean	3.00
	Std. Deviation	2.022
	Maximum	7
Bike ownership	yes: no	39%: 61%
Car-ownership	yes: no	12%: 88%
Main mode of transport (Non-cyclists only)	Private Car	19%
	Taxi	39%
	Minibus/Trotro	3%
	Motorcycle	42%
	Walking	2

Among the ‘non-cyclists’ group on the other hand, self-reported mode of transport for daily non-recreational activities (e.g. work and shopping, attending school, church/mosque), which also constituted the meaning implied by utility bicycling among the cycling population is provided in **Table 1**. Within this group, 19% reported that they had never cycled in their life. However, among the remaining 81%, their self-reported cycling history shows that they began cycling at some point between early-childhood and adulthood but have for a period of two years or more preceding this study, abandoned completely the bicycle for other modes of transport. The results further show that most non-cyclists currently participated in daily activities using the motorcycle (i.e. 42%) or the Taxi (i.e. 39%). It is therefore clear based on the survey response, and as was observed during the field work that across the population, the bicycle, motorcycle and taxi constitute the three dominant modes of transport for daily activity participation in the Tamale metropolis.

5.2 Modelling the determinants of utility bicycling

A total of 25 items were used to measure each of the latent constructs of the socio-ecological framework adopted for this study. **Table 2** shows the percentage distribution of responses to the questionnaire items according to gender (i.e. males and females) and cyclist-group (i.e. cyclists and non-cyclists) of the survey respondents. Cronbach’s Alpha coefficient ($\alpha = 0.764$; Standardised $\alpha = 0.760$) indicated highly satisfactory overall reliability and internal consistency of the questionnaire items. An exploratory factor analysis using principal axis factoring method and Varimax rotation, distilled the indicators items into seven factors (see **Table 3**).

With respect to items measuring the study participants’ perception of their physical environment in relation to cycling, four factors were extracted. These are labelled as F-1, F-2, F-5 and F-6 in **Table 3**. Based on the item loadings (i.e. difficult and dangerous road junctions, heavy and fast movement of motorised traffic, and on-street-parking street blockages), F-1 and F-2 reflect the participants’ ‘*perceived neighbourhood-scale challenges*’ and ‘*perceived metro-scale challenges*’ respectively. On the other hand, the availability of dedicated walking and cycling paths, alternative roads from origin to a destination, and traffic control systems as perceived by the respondents at the neighbourhood and metropolitan scales loaded onto factors labelled F-5 and F-6. These therefore reflect ‘*perceived neighbourhood-scale opportunities*’ and ‘*Perceived metro-scale opportunities*’ in relation to cycling.

Three items measuring attitudes—cycling being affordable and contributing less to local air and noise pollution—were correlated and thus, loaded onto a single factor (i.e. F-3) which is interpreted as the expected '*commuting benefits*' of bicycling.

Moreover, three social environment measurement items, reflecting the view that participants could cycle to important social events, the belief that the bicycle is an inferior mode of transport, and that cycling is mainly for rural folks loaded as one factor. This factor (i.e. F-4) therefore could stand for the '*status symbol*' ascribed to bicycle ownership and use in the Tamale metropolis.

Finally, the perceived influence of the approval of family members and other non-filial members such as peers and colleagues loaded as one factor (i.e. F-7), suggesting the '*influence of significant others*' on participants decision to cycle or not.

Table 2: Percentage distribution of responses to the survey items according to the gender and cyclists-group of respondents

	Male (n = 268)		Female (n = 187)		Cyclists (n =277)		Non- Cyclists (178 =)	
	A	D	A	D	A	D	A	D
There are lots of parked cars and cycle path blockages on streets in my neighbourhood	47	53	72	39	60	40	62	38
There is heavy traffic on streets in my neighbourhood	49	51	64	38	57	43	54	46
I think drivers drive too fast on streets in my neighbourhood	66	34	66	26	71	29	71	29
Neighbourhood streets are of good surface condition	56	44	70	40	64	36	59	41
There are enough dedicated walking and cycling paths in my neighbourhood	65	35	68	36	68	32	64	36
There are many traffic slowing devices on roads in my neighbourhood	45	55	61	47	53	47	48	52
Bicycling would mean I have to negotiate difficult and dangerous road junctions in my neighbourhood	51	49	58	46	54	46	53	47
There are many alternative routes for getting from place to place in my neighbourhood	73	27	67	29	73	27	54	46
I think drivers drive too fast on streets I usually use in the metropolis	70	30	66	29	68	32	69	31
There are lots of parked cars and cycle path blockages on streets in the metropolis	63	37	63	32	59	41	68	32
There is heavy traffic on streets I usually use in the metropolis	63	37	63	31	64	36	61	39
Bicycling would mean I have to negotiate difficult and dangerous road junctions in the metropolis	53	47	61	45	59	41	53	47
There are many traffic slowing devices in the metropolis (e.g. traffic lights)	58	42	60	40	69	44	62	38
There are enough dedicated walking and cycling paths in the metropolis	62	38	63	41	68	32	54	46
There are many alternative routes for getting from place to place in the metropolis	71	29	71	34	72	28	68	32
Bicycling will mean contributing less to local air pollution	70	30	66	27	70	30	66	34
Bicycling will mean contributing less to noise pollution	72	28	75	20	75	25	71	29
Bicycling saves money (affordable)	71	29	67	28	73	27	65	35
I am confident that I can bicycle	77	23	65	24	76	23	66	34
It is mostly up to me whether or not I bicycle	75	25	72	24	76	24	69	31
I believe the bicycle is an inferior mode of transport	50	50	61	43	57	43	48	52
I think I can cycle to very important social events	60	40	67	33	68	32	56	44
Cycling is for people in rural areas	54	46	69	43	43	57	56	44
With regards to cycling, other people's approval matters to me most	51	49	63	44	44	56	44	56
With regards to cycling, my close family relations approval matters to me most	51	49	65	44	43	57	44	56

Note: A = Agree, D = Disagree

Table 3: Factor loadings of questionnaire items using Varimax rotation method

	Factors						
	F-1	F-2	F-3	F-4	F-5	F-6	F-7
There are lots of parked cars and cycle path blockages on streets in my neighbourhood	0.645						
There is heavy traffic on streets in my neighbourhood	0.593						
I think drivers drive too fast on streets in my neighbourhood	0.541						
Neighbourhood streets are of good surface condition	0.457						
I think drivers drive too fast on streets usually use in the metropolis		0.733					
Bicycling would mean I have to negotiate difficult and dangerous road junctions in my neighbourhood		0.617					
There is heavy traffic on streets I usually use in the metropolis		0.578					
There are many alternative routes for getting from place to place in the metropolis		0.450					
Bicycling will mean contributing less to local air pollution			0.816				
Bicycling will mean contributing less to noise pollution			0.802				
Bicycling saves money (affordable)			0.489				
I am confident that I can bicycle							
It is mostly up to me whether or not I bicycle							
I believe the bicycle is an inferior mode of transport				0.818			
I think I can cycle to very important social events				0.656			
Cycling is for people in rural areas				0.529			
There are enough dedicated walking and cycling paths in my neighbourhood					0.570		
There are many traffic slowing devices on roads in my neighbourhood					0.569		
Bicycling would mean I have to negotiate difficult and dangerous road junctions					0.520		
There are many alternative routes for getting from place to place in my neighbourhood					0.401		
There are many traffic slowing devices in the metropolis (e.g. traffic lights)						0.476	
There are enough dedicated walking and cycling paths in the metropolis						0.439	
There are many alternative routes for getting from place to place in the metropolis						0.749	
With regards to cycling, other people's approval matters to me most							0.758
With regards to cycling, my close family relations approval matters to me most							0.620
Eigenvalues	4.567	2.562	2.026	1.672	1.402	1.326	1.231
%Variance Explained (Total = 42.29)	15.452	7.861	5.878	4.273	3.273	3.079	2.474
KMO and Bartlett's Test = 0.753 (Approx. Chi-Square = 3049.729, df = 325, p < 0.001); Cronbach's coefficient (α = 0.764; Standardized α = 0.760)							

Note: Absolute co-efficient values below 0.40 have been suppressed in the table.

A binary logistics regression model was specified in which the combined influence of the PCA factors and other socio-economic variables on whether the respondents cycled or not were examined. Results of the analysis (see **Table 3**) show that among personal characteristics variables, gender and educational attainments determined whether participants cycled or not. Being female was negatively associated with bicycle commuting in the metropolis: the likelihood of cycling among males was nearly two-and-a-half times higher compared to females. Non-tertiary educated individuals were 2.5 times more likely to cycle for utility purposes compared to those with higher levels of educational attainment. Controlling for the above socio-economic variables, individuals who owned a bicycle were about 23 times more likely to go by their daily activities using the bike.

Income as an explanatory variable was not included in the analysis as the income data obtained through the survey was not considered reliable for reasons including, reluctance to declare incomes and the tendency to underestimate earnings, especially among workers in the informal economy. Notwithstanding this, the levels of educational attainment in this context, proxies the socio-economic status of the respondents more closely than perhaps the income data would have provided. Also, our data show that 12% of the population owned and used the private car as their main mode of transport. Private car ownership is often associated with individuals of relatively higher education and income levels. Also, our data show that none of the private car owners in the sampled population owned or used a bicycle, supporting our finding that cyclists in Tamale are mainly individuals with lower levels of education and possibly lower levels of income.

The extent to which the home locations of the study respondents, broadly categorised into residence in the historical-core or suburban neighbourhoods, influenced bicycle commuting was also examined. There were almost equal proportions of historical-core (i.e. 51%) and suburban residents in the total sample of 455 respondents. The results show that controlling for other factors, individuals living in the historical-core neighbourhoods of the metropolis represented in the study were nearly twice more likely to bicycle than suburban residents. The Tamale metropolis exhibits closely the mono-centric urban spatial structure where major activities and functional uses are concentrated in the inner-core neighbourhoods. Thus, the broadly defined residential locations, which implicitly captures the physical separation between individuals' home locations and major activity locations, also reflect the influence of distance on bicycle commuting.

Table 4: Binary logistic regression analysis of the determinants of utility bicycling

	B	S.E.	Wald	df	sig	95% C.I. for EXP(B)		
						Lower	Odds Ratio	Upper
Gender (Male = 1)	0.880	0.264	11.089	1	0.001	1.436	2.410	4.044
Education (Non-tertiary = 1)	0.915	0.27	11.498	1	0.001	1.471	2.498	4.24
Marital status (Married =1)	-0.391	0.26	2.265	1	0.132	0.406	0.676	1.125
Bike ownership (Yes = 1)	3.137	0.338	86.349	1	0.000	11.883	23.029	44.628
Location (historical-core = 1)	0.550	0.261	4.431	1	0.035	1.039	1.734	2.894
Personal transport ownership (car/motorcycle = 1)	0.192	0.253	0.576	1	0.448	0.738	1.212	1.991
Perceived neighbourhood-scale challenges	-0.318	0.156	4.133	1	0.042	0.536	0.728	0.989
Perceived metro-scale challenges	-0.005	0.15	0.001	1	0.972	0.742	0.995	1.334
Commuting benefits	0.204	0.136	2.233	1	0.135	0.939	1.226	1.601
Status symbol	-0.153	0.148	1.069	1	0.301	0.642	0.858	1.147
Perceived neighbourhood-scale opportunities	0.441	0.159	7.667	1	0.006	1.138	1.555	2.125
Perceived metro-scale opportunities	0.092	0.152	0.366	1	0.545	0.814	1.096	1.475
Influence of significant others	0.155	0.149	1.08	1	0.299	0.872	1.167	1.563
Perceived neighbourhood-scale challenges * Perceived neighbourhood-scale opportunities	-0.599	0.209	8.225	1	0.004	0.365	0.549	0.827
Perceived metro-scale challenges * Perceived metro-scale opportunities	0.254	0.179	2.014	1	0.156	0.908	1.290	1.832
Constant	-1.633	0.404	16.372	1	0.000		0.195	

Notes: Nagelkerke R Square = 0.458; Cox & Snell R Square 0.338; Model fitting information: $X^2 = 187.522$, $df = 15$, $p < 0.001$; Hosmer and Lemeshow Goodness-of-fit

Test: $X^2 = 10.396$, $df = 8$, $p = 0.238$

Traffic and physical infrastructure-related factors create the physical conditions which generate either safe spaces or potential spots of conflict between motorists and non-motorists and in turn, influence cycling adoption in the metropolis. Our findings show that respondents' perceptions of physical environment conditions at the neighbourhood scale significantly influenced bicycle commuting. Neighbourhood-scale physical environment opportunities including dedicated bicycle lanes, availability of alternative roads and traffic calming systems as perceived by the respondents increased the likelihood of bicycle commuting (odds ratio = 1.56). As depicted in **Figure 2**, a network of about 51.92km dedicated bicycle lanes have been reserved mainly along principal streets for use by cyclists in the metropolis.

Figure 2: Routes with dedicated bicycle lanes in the Tamale Metropolis

Perceptions about the challenges and dangers associated with cycling correlated negatively with utility (odd ratio = 0.728), suggesting that factors such difficult road junctions, fast moving motorised traffic, and on-street parking and blockages on neighbourhood routes were major barriers to bicycle commute in the metropolis. The interaction term between perceived physical environment enabling factors, and challenges and dangers at the neighbourhood-scale also

correlated negatively with bicycle commuting, implying that the overall physical environment did not support bicycling.

Indeed, conflicts between different road users could be observed at road-junctions and major intersections in the metropolis. Through the survey, we noted about 10 major intersections on the ring-road system of the metropolis and more than 30 junctions on the arterial road system within the main built-up area where cyclists came into conflict with motorists due to the lack of prioritisation of traffic flow. Although major junctions had traffic signals, they were not sophisticated enough to time and prioritise the flow of cyclists and motorists, leading to conflicts at major intersections. Among motorists, the behaviour of motorcyclists, including unlawful use of dedicated bicycle lanes and the refusal to obey traffic signals were found to be major sources of danger to cyclists in the metropolis. Furthermore, invasion of cycling paths by small-scale businesses displaying their wares in situ and street-vendors abruptly curtailing the dedicated cycling paths, was not an uncommon scene as one approached the central areas of the metropolis.

6. Discussion and Conclusion

In this paper, we have modelled the socio-ecological determinants of bicycle commuting in the Tamale metropolis, one of the few cities in Ghana with a long history of an embedded cycling culture. Results of the analysis show that among socio-economic variables, being male and non-tertiary educated, as well as bicycle ownership, correlate positively with bicycle commuting in the metropolis. Evidence that men tend to bicycle more than women have been reported from different contexts (see. e.g. Dickinson et al., 2003; Moudon et al., 2005).

Consistent with our findings, Moudon et al., (2005), de Geus et al., (2008) and Parkin et al., (2008) found that highly educated individuals cycle less. In the case of the Tamale, this may be linked with the bike's public image as a less prestigious mode of transport as opposed to the symbolic meaning often associated with motorised transport modes, such as car ownership, as being prestigious and an indication of upward social mobility. Evidence suggests that across Ghana, there is a general negative image about the bicycle, which is associated with poverty (Integrated Transport Plan for Ghana 2010; Acheampong 2017). This could explain the preponderance of motorcycle and private car use among the majority of the non-cyclist population in the Tamale metropolis, whom the study show, are more likely to be highly-

educated. In fact, as our analyses have revealed, within the non-cyclist group, except for the few who had never cycled, the majority of them (i.e. 81%) were one-time cyclists before transitioning later to the various motorised modes of transport they currently use. The ubiquity of the motorcycle in the study area over the last few years and its use mainly among the young adult population in particular, signifies not only the pathway of transition from the pedal to motorised transport at later stages of life, but also the prestige attached to motorised transport in general as opposed to cycling.

Our results also suggest that distance separation between the home location and locations of other major activities, including work-place and shopping, and subjective perceptions of the physical environment by individuals are important determinants of bicycling in the metropolis. Consistent with previous research (Dill and Voros, 2007; Witlox and Tindemans) our study found that individuals living closer to the metropolitan centre (i.e. historical-core neighbourhoods) are more likely to undertake utilitarian trips using the bicycle compared to residents in the suburbs. Also, previous research has reported lower uptake of cycling as trip distance increases (Pucher and Buehler, 2008). With respect to the influence of physical environment factors, our findings show that individuals' perceptions of challenges and dangers such as difficult road-junctions, the behaviour of motorists, and on-street parking correlate negatively with bicycling while factors such as dedicated bicycle lanes, alternative routes to get between places and availability of traffic control systems, all of which reflect positive neighbourhood environment perceptions, increase bicycle commuting.

In Ghana, the need to promote active transportation, including bicycling is recognised in the National Transport Policy, which sets an ambitious target of achieving a 10% increase in non-motorised transport (Government of Ghana, 2008). The current study, besides pointing to a huge potential for cycling in the Tamale metropolis, highlights the major challenges to bicycle commuting that require addressing in order to remove barriers to cycling. Based on our findings, expansion of existing bicycle lanes whilst freeing designated lanes of street-trading activities blocking them, investment in traffic calming measures and modern traffic control systems that reduce conflicts by prioritising cyclists would be some of the practical ways of removing the barriers to cycling. Cycling promotion interventions could also address negative image associated with cycling and educate motorists about traffic regulations and ways in which they could contribute to ensuring the safety of other road users including cyclists.

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