Mode Choice Analysis for Non-Motorized Transportation Facility Design Inside the University of the Philippines Los Baños

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Abstract: Walking and bicycling, forms of non-motorized transportation (NMT) modes have been considered the most effective ways for improving mobility while keeping the environment clean. This study assessed factors and their effects on how users choose NMT modes such as bicycling and walking, against other modes such as jeepneys and cars. Using data that were collected from respondents through the aid of survey questionnaires, a discrete choice model was estimated. Findings show that factors that have the greatest effect on the choice of mode of transportation, include the travel time, travel cost, weather condition, and rental facilities. The results can provide insights that help understand how the probability of NMT users can be increased. The results became the basis for designing a proposed NMT facility for use in the university.

Keywords: mode choice, non-motorized transportation, bicycling, walking, university

1. INTRODUCTION

Like some other built-up areas, universities or college campuses are places where many human activities occur (Dell'Olio *et al.,* 2014). As the number of employees, students, and professors inside university and college campuses increases, the number of motorized vehicles inside the campus also increases rapidly (Xu *et al.,* 2012). The increasing number of motorized vehicles may lead to traffic-related problems such as congestion, air pollution, noise pollution, and high accident rates (Rybarczyk & Gallagher, 2014). Due to this, many universities and colleges are aiming for a more sustainable means of transportation inside their campuses, which may result in a more attractive university environment. This may also create a more active way of living inside the campus.

The use of NMT is one of the best options as it proposes a lot of benefits including health, environmental, economic, and mobility (e.g. Tilahun *et al.,* 2007; Bagloee *et al.,* 2016). NMT is any form of human-powered transportation. It is any trip made to go to a certain destination such as work, school, store. NMT, including modes such as walking, bicycle, handcart, pedicabs, etc., are seen to be useful in short-distance travels (Bamney and Tiwari, 2020).

However, it is also being used for long commutes up to 10-km distance (Chen *et al.,* 2019; Castro and Josef, 2020; Ye *et al.,* 2020). Walking and cycling are the most popular forms of NMT (Ma and Dill, 2015). These, when used as a regular means of transportation have been considered as the most effective way to improve the health of an individual. The use of these modes is more satisfying than motor vehicles (Lades *et al.,* 2020). To encourage more people to travel through these modes of transportation, it is important to provide an enabling environment. These include but are not limited to policy, environment, and infrastructure.

Research was done to understand the mode choice of students in Asia (eg. Yazid *et al.,* 2011; Rybarczyk *et al.,* 2014; Negrite, 2015; Bamney and Tiwari, 2020). However, limited studies have been done to understand the choice of students, faculty, and employees in universities or colleges. In the Philippines, Universities acknowledge the benefits of utilizing NMT as a mode of transportation on the campuses. However, implementation has not been sustained, and replicability has not been successful (Negrite, 2015, Gozun, 2016). These may be due to the lack of understanding of the context and preferences of target users. In this line, it is important to understand the complex factors aligned to the choice of target users. In past studies, socio-demographic characteristics of target users are influential factors to the choice of mode. For instance, age, marital status, gender, occupation, income level, and vehicle ownership increase the likelihood of NMT use (e.g. Tilahun *et al.,* 2007; Barberan *et al.,* 2017; Bamney and Tiwari, 2020; Liu *et al.,* 2020). However, it was found that socio-demographic factors are not predictors of NMT use (Lundberg and Weber, 2014). Results of past studies are rather specific to the context of the study area.

In addition, weather, topography, and travel-related factors such as travel time and distance are found to affect NMT use (e.g. Ma and Dill, 2014; Chillón *et al.,* 2016; Hong *et al.,* 2020). Also, building facilities or infrastructures with proper design can not only help increase the safety of the users, but it may also promote the use of NMT. Facilities and infrastructure like bicycle lanes, shared lane markings, side paths, parking, among others, increase the number of bicycle users (Ranck and Ronkin, 2006; Lundberg and Weber, 2014; Ozawa *et al.,* 2021). Like pedestrian facilities, networks with good connectivity, and shortness of paths also show the importance of using a bicycle as it saves time and energy (e.g. Bradley *et al.,* 2014). Improving pedestrian paths and cycling zone to increase NMT use and reduce motor vehicle travel (Yazid *et al.,* 2011). However, only the built environment effects to safety and walkability are considered in studies (e.g. Blitz *et al.,* 2020). It is important to consider design functions which may further guide the effects of the built environment to NMT use (Blitz *et al.* 2020). Despite the importance of inclusion of facilities and infrastructure to improve usage had been insufficient across many areas that have been identified to have a potential for bicycle use. Such insufficiency was observed in the context of local universities that have the potential for cycling such as that in campuses of the University of the Philippines in Diliman and UPLB (Gozun, 2016; Negrite, 2015). Gozun (2016) further cited the unavailability of bicycles for use and the inability to use bicycles to be significant barriers to cycling use among university students.

The main purpose of this research study is to explore the use of NMT on the campus especially for short-distance travels within 2 kilometers. Specifically, this study identified the different factors that affect the use of NMT inside the University of the Philippines Los Baños (UPLB). Results in this study are targeted to encourage more people to use bicycles and walking as a mode of transportation. Based on the study results, the design of NMT facilities and infrastructure appropriate inside the campus is proposed. This study also assessed the existing infrastructure that can be developed for an NMT system in UPLB.

2. LITERATURE REVIEW

2.1 Factors Affecting Mode Choice

Mode choice is a complex decision that involves many determinants at various levels. To further understand the mode choice of people in a greater depth, identifying the influential factors to decision making is necessary. Studies have investigated the factors that influence the type of mode of transportation they use (Cameña and Castro, 2016; Barberan *et al.,* 2017; Liu *et al.,* 2020; Reck *et al.,* 2021; Scheffer *et al.,* 2021). NMT is influenced by many different factors such as the built environment, facilities, and infrastructure, the natural environment, socio-demographic factors, and travel-related factors. Factors found to influences NMT use in past studies are discussed below and are summarized in Table 1.

Respondents' socio-demographic characteristics play an important role in the use of NMT. Characteristics found to influence cycling and walking include age, gender, income, educational level, marital status, and other characteristics of the respondent. The effects of these characteristics on the likelihood of using NMT had been documented in several pieces of research (e.g. Tilahun *et al.,* 2007; Cameña and Castro, 2016; Verma *et al.,* 2016; Aldred *et al.,* 2017; Bamney and Tiwari, 2020). Age is generally reported to have negative correlations on the likelihood of using a bicycle (Piatkowski and Marshall, 2015; Barberan *et al.,* 2017; Chen *et al.,* 2019). Older people who have stronger preferences on separated cycling infrastructure are positively linked to shifting behavior (Aldred *et al.,* 2017). Further, unmarried commuters were found to be more inclined to change their commute modes to NMT use (Liu *et al.,* 2020). Also, females are more likely to shift to NMT with mandatory trips as compared to males (Bamney and Tiwari, 2020). Females usually use bicycle in making their trips for shopping, recreational trips, and others, while men use bicycle to work (Tilahun *et al.,* 2007). Comparatively less than 40 percent of men's trips are for family and personal business and 18 percent of men's trips are for commuting to work or school (Verma *et al.,* 2016).

Further, income and educational levels are also associated with the use of bicycles. People with higher income who use the bicycle are lower compared with people with lower income (Verma *et al.,* 2016). In the case of India, people with low incomes are more likely to walk as their mode of transportation (Cao *et al.,* 2006). It was also found that cycling is mostly used by lower-middle-income society in India (Bamney and Tiwari, 2020). The low bicycle usage among high-income individuals is linked to the greater mode of share of automobiles across this income group (Cameña and Castro, 2016; Barberan *et al.,* 2017). In addition, people with a college degree showed 2.8 greater possibilities to use the bicycle for recreational uses compared to commuting (Cao *et al.,* 2006). Although the above-mentioned studies found that socio-demographic factors influence NMT use, factors such as age, and marital status are not predictors of NMT (Lundberg and Weber, 2014).

Moreover, the environment can affect the type of transportation mode used. Ma and Dill (2014) found that weather and climate were the most significant deterrent to cycling use workers in Metro Manila (Castro and Josef, 2020). Similarly, a decrease in bicycle usage due to inclement weather was found (Hong *et al.,* 2020). In addition, Allen-Munley *et al.,* (2004) reported that steep slopes were associated with a decrease in the likelihood of shifting to bicycle. Moreover, studies had shown that commuting on bikes is good for short distances within a 10 km distance range (Castro and Josef, 2020; Ye *et al.,* 2020). Chen *et al.,* (2019) had shown that public commuters who travel a distance greater than 10 km are linked to less likelihood of shifting to bicycle use. Heinen *et al.,* (2011) suggest a positive correlation to long-distance commutes among working individuals. In addition, Liu *et al.,* (2017) report the same relationship of distance in the case of commuting in private bicycle use, at a maximum average distance of 5 km in the case of university students (Chillón *et al.,* 2016). However, it is important to consider that the study area is a cycling-friendly area. Also, Barberan *et al.* (2017) found that bicycles are less used in shorter commutes with distances less than 1 km as walking might become more attractive at these distances. Additionally, there is a decrease in willingness to shift to NMTs just after 3 km of travel distance (Bamney and Tiwari, 2020).

Subjective trip characteristics, such as safety and convenience, also play important roles in the University setting (Lades *et al.,* 2020). Moreover, the cost of travel was also shown to have varying effects on the likelihood of using a bicycle (Liu *et al.,* 2020). Meanwhile, Chen *et al.,* (2019) found a positive relationship between the cost of travel and the likelihood to shift to bicycles in the case of bike-sharing initiatives. In terms of trip purpose, trips to school among respondents below 18 years old were highly associated with using NMT (Bamney and Tiwari, 2020). In addition, the environment, weather, temperature, precipitation, and topography are the factors needed to be considered in encouraging the usage of NMT (Bradley *et al.,* 2014). For bicycle users, weather like light and heavy rain, strong wind, hours of sunshine, and apparent temperature affect the cyclist's performance (Spencer *et al.,* 2013). Bicycle users might bear traveling in certain weather conditions like extreme heat, cold, or light/heavy rain for a short period (Böcker and Thorsson, 2014). For pedestrians, the number of people walking decreases during the rainy season and extremely hot weather. Temperature is also a factor that can cause discomfort for both pedestrians and cyclists. Both pedestrians and cyclists prefer to travel in warm temperatures than cold temperatures. For temperatures lower than 32 degrees Celsius, there are more bicycle activities than during times when temperatures are high (Bradley *et al.,* 2014). Also, active users who travel on slight to steep slopes involve extra effort to climb an upward sloping area and require more caution traveling on downward sloping areas (Gupta *et al.,* 2017). Bicycle users are more sensitive when it comes to steep grades than pedestrians. When it comes to utilitarian use, NMT users prefer routes with plain topography as it requires less energy and can be traveled faster than areas with mild to steep slopes.

Further, the built environment acts as a surrogate for socioeconomic factors that affect travel behavior (Tilahun *et al.,* 2007; Cao, Handy, & Mokhtarian, 2006). Pedestrian and bicycle facilities can be described as facilities or infrastructures that help increase the safety of the users (Ranck and Ronkin, 2006; Flusche, 2012). Higher amounts of bicycle-friendly infrastructure, such as bicycle lanes, paths, bicycle boulevards, or off-street trails, have the potential to increase the likelihood of bicycling (Lundberg and Weber, 2014). Cyclists perceive bicycle parking to be important (Heinen and Buehler, 2019; Castro and Josef, 2020). In terms of proximity, Krizek and Johnson (2006) found that on-street bicycle lanes had a greater likelihood of bicycle use among respondents are recorded within a 400-meter area within the proximity of the facility. Research shows that users are more likely to use a shared bicycle at distances less than a kilometer which supplements the solution brought by these stations (Ye *et al.,* 2020). However, the selection of the location of these stations may also account for the trends in usage as stations with less usage may lead to inefficiency of the system due to relocation. Studies had shown that balanced demand was found in places of leisure and education while large reallocations were observed among residential and commercial areas (Zhao *et al.,* 2019). In terms of increasing walkability in an area, the presence of sidewalks, in addition to road width, the number of steps, and considered (Ozawa *et al.,* 2021). In addition, the development of facilities supporting the pedestrians such as white lines on pavements, pedestrian signals at crosswalks, and installation of roofs and handrails at pedestrian bridges is important (Ozawa *et al.,* 2021).

Table 1. Factors that Influence the Use of Cycling and Walking

Author/s	Determinants Category	Factors that Influence NMT Use
Ozawa *et al.,* 2021	Built environment and Facilities	walkability in an area can be increased with presence of sidewalks, width of roads, obstacles, pedestrian security, pedestrian crosswalks and bridges, white lines on pavements, pedestrian signals at crosswalks, and roofs and handrails at pedestrian bridges
Castro and Josef (2020)	Built environment and Facilities; Natural environment; Travel characteristics	bicycle lanes, bicycle parking, climate, travel distance
Ye *et al.* (2020)	Travel characteristics; Built Environment & Facilities	travel distance, presence of parking stations
Liu *et al.* (2020)	Travel characteristics	travel cost
Lades *et al.* (2020)	Travel characteristics	duration of the trip, safety, and convenience
Bamney and Tiwari (2020)	Socio-demographic factors	age, gender, occupation level, income level and vehicular ownership
Chen *et al.* (2019)	Travel characteristics	travel distance, cost
Benedini *et al.* (2019)	Socio-demographic factors	income
Heinen and Buehler (2019)	Built Environment & Facilities	bicycle parking
Chevalier *et al.* (2019)	Built Environment & Facilities	suitable infrastructure for cycling, better treatment of built environment for cycling
Gupta *et al.* (2017)	Natural Environment	active users who travel on slight to steep slopes involves extra effort to climb an upward sloping area and requires more caution traveling on downward sloping areas
Barberan *et al.* (2017)	Travel characteristics	distance
Cameña and Castro (2016)	Socio-demographic factors, travel characteristics	personal preference, flexibility in modes
Ma and Dill (2015)	Built Environment & Facilities	influence the behavior or perception of the user
Bradley *et al.* (2014)	Natural Environment	climate, weather, visibility, temperature, safety
Spencer *et al.* (2013)	Natural Environment	for bicycle users, weather like light and heavy rain, strong wind, hours of sunshine, and apparent temperature
Ranck and Ronkin (2006)	Built Environment and Facilities	pedestrian and bicycle facilities
Cao *et al.* (2006)	Socio-demographic factor, Built Environment and Facilities	income, built environment
Krizek *et al.* (2004)	Socio-demographic factor	gender

2.2 Geometry and Design Consideration of NMT

As mentioned earlier, building facilities or infrastructures with proper design can not only help increase the safety of the users but may also promote the use of NMT. This section presents the biking and walking facilities and standards that should be considered in the design. This will cover both pedestrians and facilities for a bicycle.

2.2.1. Pedestrian Facilities

A good route for pedestrians should provide enough space for pedestrians to travel, pass and gather. A well-maintained surface should be firm, stable, slip-resistant, and free of vertical obstructions like lips and bumps (Ranck and Ronkin, 2005). Sidewalks are walkways that are parallel to a street or a highway usually within the public right of way. Sidewalk surfaces should be firm, stable, and slip resistant. Properly planned sidewalks are essential in providing pedestrian mobility, safety, and accessibility, particularly for persons with disabilities, children, and older adults. Sidewalks reduce the incidence of pedestrian collisions, injuries, and deaths in residential areas and along the two-lane roadway (Ranck and Ronkin, 2005). There are various characteristics in which the design of a sidewalk can be described. This paper is merely focused on the characteristics of a sidewalk that may greatly influence accessibility, grade, and type of surface. Some characteristics such as location, street type, and climate may cause unwanted repercussions but would not directly impact access. The functionality of a sidewalk is directly affected by the access characteristics. Even the slightest difficult feature in combination can risk the accessibility of the pathway. Grade, defined as the slope along the travel direction is also an important feature. This is calculated by the vertical change in elevation divided by the horizontal travel distance (Axelson and McMillen, 2015). Sidewalks should be designed with maximum grades of 5 percent (1:20) where possible, considering the need of users with disabilities. Grades which are more than 5 percent should include handrails and level landings of at least 1.525 m width. Moreover, when including a turning ramp, the landing dimensions should be 1.525 m x 1.525 m (Axelson and McMillen 2015). Sidewalk widths vary from 1.2 to 2.4m. In addition, planted strip width between the sidewalk and traveled-way curb, when included should be at least 0.9 m. This is to allow space for maintenance activities (AASHTO, 2012). Most guidelines for vertical clearance require at least 2.030 m of unobstructed vertical space. ADAAG specifies that for vertical clearance next to a circulation route of less than 2.030 m, a barrier must protect elements that project into the circulation space. This is to warn people who are visually disabled or blind (ASSHTO, 2012).

2.2.2. Bicycle Facilities and Infrastructure

Width is the most critical variable affecting the ability of a roadway to accommodate bicycle traffic (Xu, Zhang, & Rong, 2012). Bicycle lanes indicate a preferential or exclusive space for bicycle travels along an arterial street. It has been found to give more consistent separation between the bicyclist and passing motorist. Bike lanes are designated by striping and marking the road, although in certain situations colored pavement has been used to separate the bike lanes to motor vehicle lanes (Zegeer, 2002). Bicycle lanes also serve as a buffer between motor vehicle traffic and pedestrians when sidewalks are immediately adjacent to the curb. The location of bicycle lanes is located on both sides of the street. Bicycle lanes should not be separated from other motor vehicle lanes by curbs, parking lanes (AASHTO, 2012). The minimum width for a two-directional shared use path is 10 feet or 3 meters (AASHTO, 2012). Moreover, it is recommended that the width of a shared-use path be increased to 3.3-3.5 meters to accommodate cycling, jogging, skaters, and people walking, among other NMT use (Brustlin, 2013).

2.2.3. Shared-Use Path

Shared use paths are facilities on exclusive right-of-way within minimum cross flow by motorized transportation modes (Brustlin, 2013). Target users of a path should be identified early in the design process to consider appropriate accommodation and identify ahead the address potential conflicts. This may be an existing roadway, street with wide curb lanes, or a road with paved shoulders. The minimum usable width of a wide curb lane for shared roadways should be 4.2 meters. The usable width, usually measured from the edge stripe to the centerline or adjacent lane stripe, and the gutter pan should not be included as usable width. According to the AASHTO Guide for the Development of Bicycle Facilities (AASHTO, 2012), it may be more appropriate to use a wider curb lane typically up to 4.5 meters on steep grades where the bicyclist needs more maneuvering space.

3. METHODOLOGY

3.1 Study Area

UPLB is known as the largest university in the Philippines in terms of land area. It is in the town of Los Baños, lying within 14.1648° latitude and 121.2413 longitudes, near the foot of Mount Makiling. The real estate holding of the campus covers a total of 14,665 hectares and a total complex land area of 5,445 hectares. The complex area consists of more than 300 buildings and 12 libraries. The buildings inside the campus are widely spread out through the land area which makes the distances between the buildings lengthy. The natural physical features of the area make it difficult to construct roads and other infrastructures. Figure 1 shows the map of the lower campus of the University of the Philippines Los Baños.

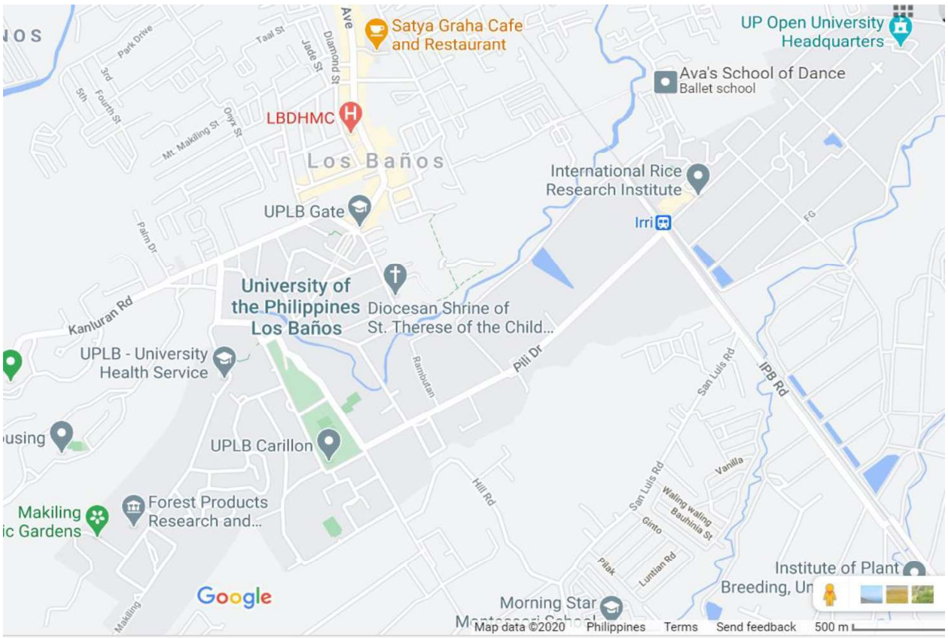


Figure 1. Map of UPLB located in the Province of Laguna
Source: Google maps (2020)

The population of the university in 2017-2018 was 11, 461 students. Students contribute most to the population on the campus. Most of them do not use or own any personal vehicle and prefer only to commute or walk. Table 2 shows the breakdown of the students enrolled in the university for the SY 2017-2018.

Table 2. Breakdown of the Population of UPLB Students (SY 2017-2018)

Type of Student	**Population**
Undergraduate	8480
Certificate in Forestry	76
Non-Regular Students	32
Graduate	2120
Highschool	753
Total	11461
Male	4900
Female	6561

Source: UPLB Registrar (2018)

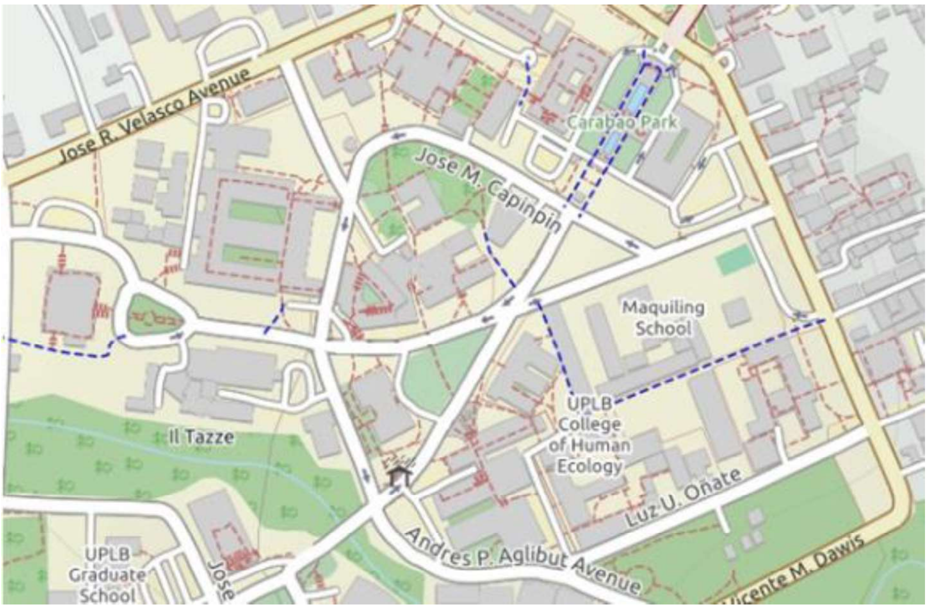
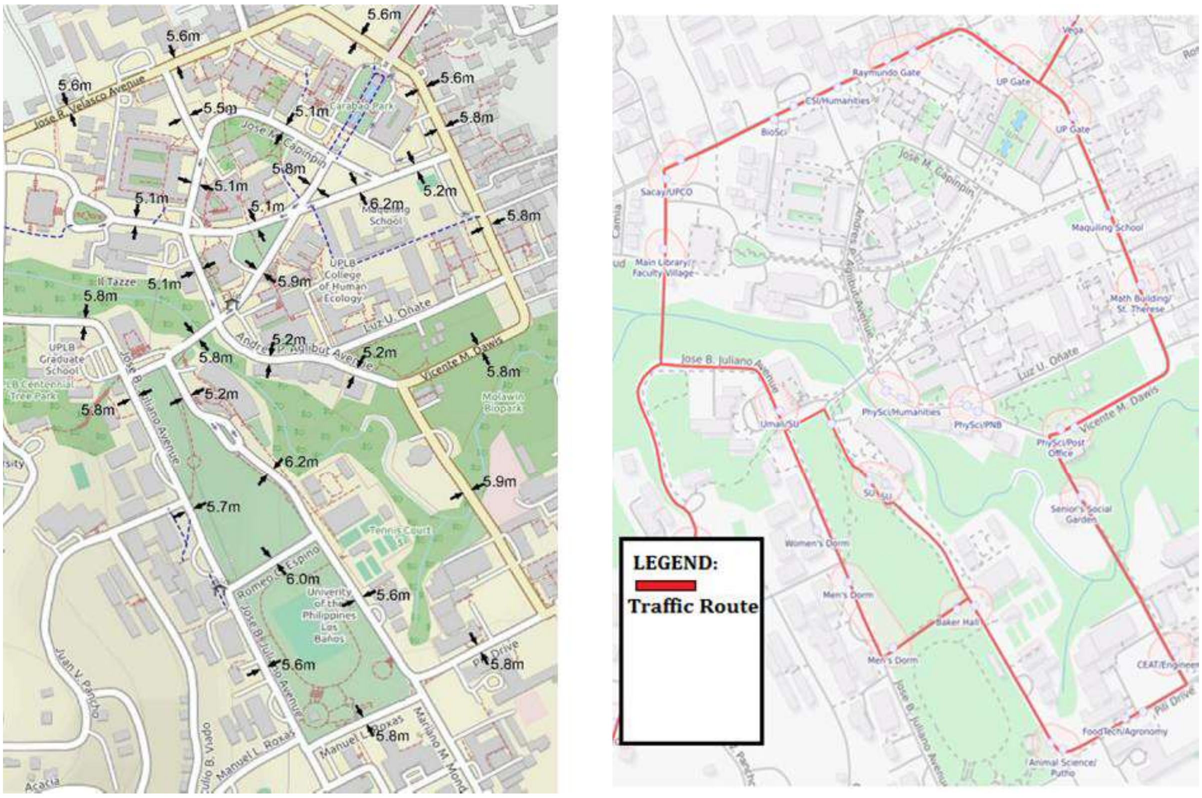


Figure 2. Traffic Flow in the Middle Campus
Source: Open Street Map (2018)

The arrows in Figure 2 indicate the traffic flow inside the middle campus. The AASHTO Guidelines require the identification of the width of a road to determine if a road can be used for a bicycle lane, shared-use path, or shared roadway. Figure 3a shows the width of roadways that are considered in the placement of the routes for different types of roadways. The width of the roads that the researchers got from previous research in UPLB was used to determine if it was greater than the minimum width of the road for each type of roadway required by the AASHTO Guideline.



(a) (b)

Figure 3. Road Network Inventory (Source: Negrite, 2015) and Traffic Route in the Lower Campus (Source: Open Street Map, 2018))

Figure 3b shows the current traffic route of PUJs in the lower campus. This route was implemented in 2007 and is still being used. Jeepneys are not allowed to travel in the middle campus. This route was used as a guide by the researchers to assess the possible bicycle lanes, shared-use paths, and shared roadway.

3.2 Data and Analysis

A survey questionnaire was designed to gather information from the respondents regarding their choice of modes from a personal car, jeepneys, to walking and cycling. The survey questionnaire was composed of 3 sections. The first part centered on the information of the survey respondents. This contained personal information such as age, gender, and vehicle ownership, and accommodation type. This also accounted for the socio-economic background of the respondent. The second part of the survey questionnaire contains travel and environment characteristics including the travel distance, cost, waiting time, travel time, and the weather. The third part consisted of facility-related information especially for bicycles or pedestrian paths. 170 observations from students at UPLB were used for analysis. In this survey, more females participated than males, with 52.4% of the overall participants. Most of the respondents (46.5%) are 19 to 20 years of age. About 51% of female and 42% male participants who responded were about 19-20 years old. The collected data were classified and tabulated according to the categories of the responses. The data were cross-checked for consistency from the data used for analysis. Table 3 shows the categories, frequency, and percentage of variables used for analysis. More than 55% of the respondents chose NMT. While the rest chose to use other modes of transportation.

Table 3. Summary of Variables Used for Binomial Model of Mode Shift to NMT

Variable	Category	Number	Percentage
Mode of Transportation (MOD)	NMT (bike/ walk)	95	55.88
	Others (jeepney, personal car)	75	44.12
Socio-economic information			
Gender (GEN)	Female	89	52.35
	Male	81	47.65
Age (AGE)	≤ 18 years old	47	27.65
	19-20 years old	79	46.47
	≥ 21 years old	44	25.88
Monthly allowance (AL)	800-1000 pesos	55	32.35
	1001-1200 pesos	24	14.12
	1201-1400 pesos	25	14.71
	1401-1600 pesos	32	18.82
	1600+ pesos	34	20.00
Accommodation type (ATYP)	Own House	46	27.06
	Dormitory	60	35.29
	Others	64	37.65
Travel and environment characteristics			
Travel Distance (DIST)	≤ 520 meters	59	34.71
	521-1040 meters	52	30.59
	1041-1560 meters	40	23.53
	≥ 1561 meters	19	11.171
Travel Time (TT)	≤ 5minutes	77	45.29
	>5 minutes	93	54.71
Travel Cost (TC)	No cost (0)	97	57.06
	7 pesos	73	42.94
Waiting time (WT)	≤ 5 minutes	86	50.59
	5-10 minutes	66	38.82
	11-15 minutes	11	6.47
	≥16 minutes	7	3.12
Weather (WEA)	Yes	146	85.88
	No	24	14.12
Bicycle facilities			
Presence of bike lanes	Present	107	62.94
(BLAN)	Not present	63	37.06
Presence of Parking/	Present	111	65.29
Stations (STA)	Not present	59	34.71
Rental facilities (RENT)	No cost	118	69.41
	With cost	52	30.59
Distance (TDIST)	Yes	99	58.24
	No	71	41.76

3.3 Modeling Framework

The framework of discrete choice is utilized in this study. The discrete choice models are being widely used for analysis of factors that influence the decision-making process. It presents an informative way of analyzing outcomes recognizing that the dependent variables are a set of categorical or ordinal forms. The model postulate that an alternative is selected if the utility is higher than the utility of other available alternatives. Then the probability of selecting an alternative with a utility higher than other alternatives is the outcome of the model. Extensive application of discrete choice models in many disciplines exists in the literature (e.g.

Pryanishnikov and Zigova, 2003; Zhang *et al.,* 2009; Zaghdoudi, 2013). The logit model is one form of the discrete choice model (Train, 2009). The logit model is simple and in a closed-form estimation. It can capture the behavioral context of mode choice decision-making. It is generated with the assumption that the random terms are distributed IID Gumbel which was also called Weibull. The binomial logit (BNL) model is used when there are more than two alternatives. The BNL model was the choice of mode in this study.

Decision-makers for mode choice in this study are the respondents from UPLB. Choice alternatives considered in the BNL model for mode choice include the NMT (bicycling or walking) and other modes (jeepneys, private car). The variables used in the estimation of the BNL are detailed in Section 4.1. Any respondent, *i* choosing NMT, *n*, or other modes, *o*, respectively, is represented with a utility function indicated as Equations 1 and 2, respectively. The terms βQ_{ni} and βQ_{oi} are parameter vectors that are estimated for the respondents, *i*, choosing modes *n* or *o*, respectively. λR_{ni} and λR_{oi} are parameter vectors that determine the respondent's mode choice of either NMT, *n,* or other modes, *o*, respectively. $\boldsymbol{\beta}$, and λ are vectors of coefficients to be estimated for *Q*, and *R* respectively. $\boldsymbol{\varepsilon}$ are the error terms that consider the effects of unobservable factors, the preference differences, and the use of proxy variables on observed choice.

$$\boldsymbol{MC_{ni} = \beta Q_{ni} + \lambda R_{ni} + \varepsilon_{ni}} \tag{1}$$

$$\boldsymbol{MC_{oi} = \beta Q_{oi} + \lambda R_{oi} + \varepsilon_{oi}} \tag{2}$$

The probability of the outcome of a mode decision *j* of the respondent, *i* are shown in Equations 3 and 4, where *j* indicates the outcome mode decision of which includes NMT, *n,* and others, *o*.

$$\boldsymbol{P_{ni}} = \frac{e^{\beta Q_{ni}+\lambda R_{ni}}}{e^{\beta Q_{ni}+\lambda R_{ni}} + e^{\beta Q_{oi}+\lambda R_{oi}}} \tag{3}$$

$$\boldsymbol{P_{oi}} = \frac{e^{\beta Q_{oi}+\lambda R_{oi}}}{e^{\beta Q_{ni}+\lambda R_{ni}} + e^{\beta Q_{oi}+\lambda R_{oi}}} \tag{4}$$

The coefficients *β'* in Equations 1 and 2, were determined by using the method of maximum likelihood estimation. The log-likelihood function is presented in Equation 5, where *I* indicate the number of respondents and *J* indicates the type of mode choice.

$$\boldsymbol{LL} = \sum_{j=1}^{J} \sum_{i=1}^{I} log(P_{ni}) \log\,(P_{oi}) \tag{5}$$

The stepwise backward elimination was used to select the variables included in the model. This method is an effective way of reduction of variables from among many explanatory variables (Steyerberg *et al.,* 2004). In this method, all variables were gathered and tested for significance. Then, each variable was assessed whether to be included in the model by looking at the *p* values. Variables with p values greater that the level of significance were removed one at a time. The remaining variables were repeatedly subjected to statistical tests until the desired combination of variables that provides for a model that is significant. The model specification validity was tested using an LR-based statistical test. The McFadden *pseudo-*R^2 was used to evaluate the goodness of fit of the model. Stata Version 13.1 was used to estimate the BNL model. Stata is a complete, mixed statistical software package that provides various results for data analysis, data management, and graphics. Stata is software that allows its user to store and organize data, either in small or large data sets. This software is commonly used by researchers with very large data sets because this software allows you to do almost anything you like with your data.

4. RESULTS AND DISCUSSION

This section includes the results and discussion of model estimation as well as the proposed design of the NMT facilities and infrastructure.

4.1 Model Estimation

The researchers used the BNL model to assess the probability of what mode of transportation the respondents in UPLB are willing to use. The mode of travel which is NMT or other modes (jeepney, private car) was analyzed as the dependent variable, while other variables as indicated in Table 3 were used as the independent variables. "Other modes", was used as the basis for estimation of the NMT BNL model. After performing the stepwise elimination of variables included in the BNL model, the variables included were travel distance, travel time, rental facilities, and weather. Results of the model are indicated in Table 4. The resulting BNL model had a *p*-value of 0.000. Hence, the model is significant. This also indicates that a relationship between the dependent variable and independent variables exists. This further means that the choice of mode of transportation is related to travel distance, travel time, rental facilities, and the weather. Moreover, the value from the model for R^2 is 0.376 which indicates a decent fit. The model R^2 of 0.3 or greater in a discrete mode choice has a decent model fit (Hensher *et al.,* 2005).

Table 4. Results of Model Estimation for Using NMT

Mode Choice Variable	Coef. β	Std. Err.	z	P > |z|
Travel distance, DIST (1 for travel distance less than 1 km; 0 for more than 1 km)	2.074**	0.316	6.57	0.000
Travel time, TT (1 for travel equal or less than 5 minutes; 0 for more than 5 minutes)	-0.784*	0.472	-1.66	0.097
Presence of bike rental facilities, RENT (1 for presence of rental facilities; 0 otherwise)	-1.039**	0.479	-2.17	0.030
Weather during traveling, WEA (1 for good weather condition, 0 otherwise)	1.616**	0.750	- 2.16	0.031
Number of observation = 170				
LR $chi^2(4)$ = 87.67				
Prob > chi^2 = 0.000				
Log Likelihood = -72.82				
R^2 = 0.376				

**significant at 90%; **significant at 95%*

Table 4 summarizes the results of the model estimation for a mode of transportation. It can be observed that findings in this study show that socio-demographic characteristics of respondents are not predictors of NMT use. This goes with findings in Lundberg and Weber (2014). Four parameters were found to be significant in choosing a mode of transportation. Travel distance, travel time, rental facilities, and weather have the most significant effects on the mode of transportation decision. The coefficient β values indicate if the probability of the user to choose either NMT or other modes of transportation. Positive values indicate that users have a higher chance of choosing NMT, and negative values indicate a higher chance of other modes being chosen.

For the travel distance, the coefficient β= 2.074 indicates that the shorter the travel distance, the more likely that users choose NMT as a mode of transportation. This also indicates that users prefer to use other modes if the travel distance is farther than 1 kilometer. This result is logical and goes with previous findings. Barberan *et al.,* (2017) found that bicycles are less used in shorter commutes with distances less than 1 km and walking might become more preferred. Also, Bamney and Tiwari (2020) record the decrease in willingness to use NMTs just after 3 km of travel. This also goes with the findings of Chen *et al.,* (2019), Castro and Josef (2020), and Ye *et al.,* (2020) where less likelihood of using bicycles within distances of 5-10 km is observed. However, in an existing cycling-friendly environment, travels of distances up to a maximum of 5 kilometers are happening where the facilities and environment already support such use (Chillón *et al.,* 2016; Liu *et al.,* 2017). This may be seen in the context of this study in the long run due to the good environment in the University.

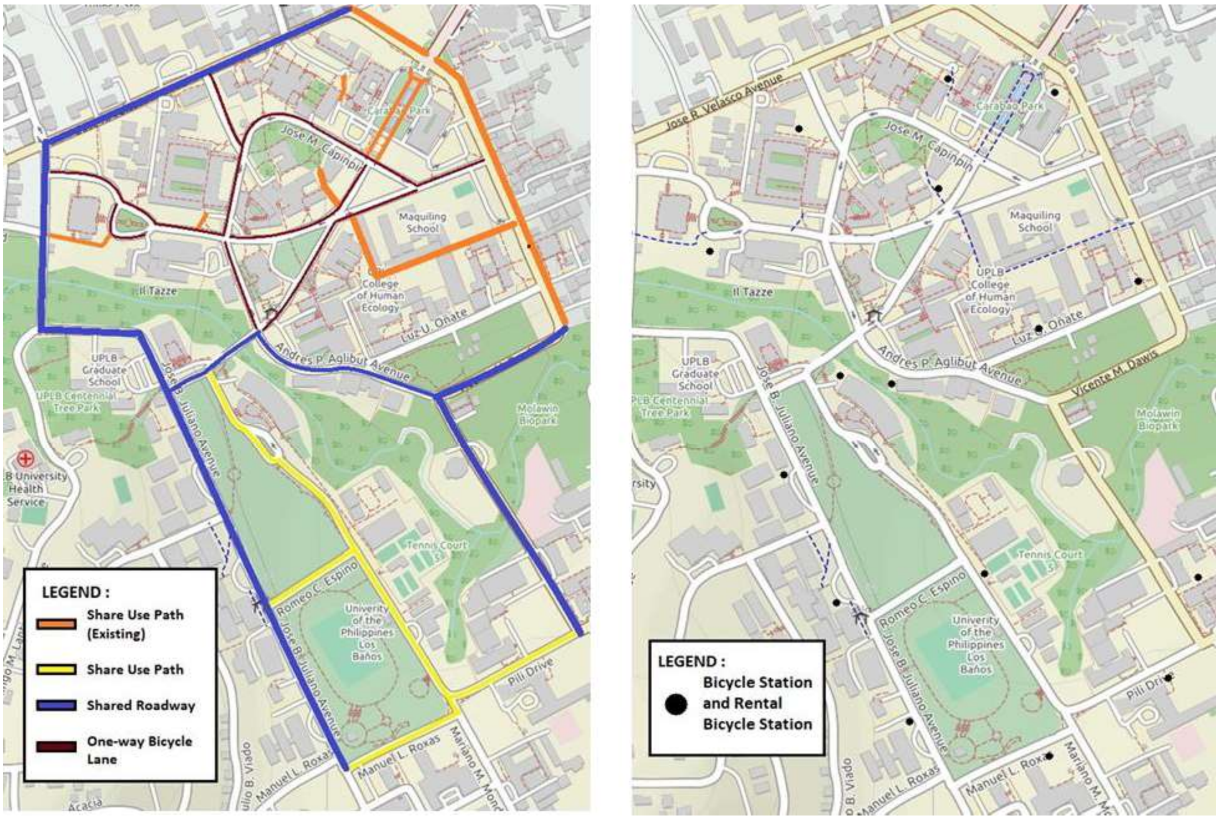
In addition to factors found to influence NMT use in UPLB, travel time has a negative coefficient of β=-0.784. This indicates that the shorter the travel time, the more likely that users choose NMT. It also implies that with longer travel time, the users prefer other modes than NMT. This result is logical and may be related to the cost of travel and may be related to past studies' results. Cost of travel and likelihood to use bike-sharing was observed (Chen *et al.,* (2019). However, the study focused on bicycle use and not those who choose to walk. This inference can be further investigated. Moreover, Liu *et al.,* (2020) found varying effects of the cost of travel towards bicycle usage. Further, the cost of travel may also be related to the rental facilities. In this current study, results show that have a negative coefficient of β (-1.039) value exists between the NMT use and rental for bicycle use. This means that if rental fees are imposed in using bicycles and related facilities, respondents are less likely to use NMT. This indicates that people have a higher probability of using facilities for free. This suggests that management of facilities in the first few years should be provided to potential users in the University for free.

Weather is also a significant factor in the mode of transportation decision. The coefficient β=1.616 is positive. This indicates that users have a higher probability of utilizing NMT when the weather is good. The possibility of users choosing other modes is higher when it is raining, or when the weather is hot. It may also be otherwise if it is drizzling or raining lightly. It is still likely for users to walk in this case. This finding supports past literature findings. A decrease in bicycle usage due to inclement weather was found (Hong *et al.,* 2020). Also, weather like light and heavy rain, strong wind, hours of sunshine, and apparent temperature affect the cyclist's performance (Spencer *et al.,* 2013; Böcker and Thorsson, 2014). For those that walk, the number decreases during the rainy season and extremely hot weather (Bradley *et al.,* 2014). These findings in the current study suggest that the provision of a covered pathway for NMT users may increase the probability of more people using such a mode.

Based on the above results in this study, the infrastructure development and needs to encourage more people to use NMT inside UPLB are designed in the next section. The existing routes for transportation where designated lanes with covered paths can be built are determined. These and other design details according to AASHTO standards are discussed in the next section.

4.2 Proposed Design of NMT Facilities and Infrastructure

Figure 4a shows the different types of routes in UPLB, both existing and possible routes for NMT users in the University. The possible routes were determined using the AASHTO Guidelines and were affected by the results of the road network inventory.

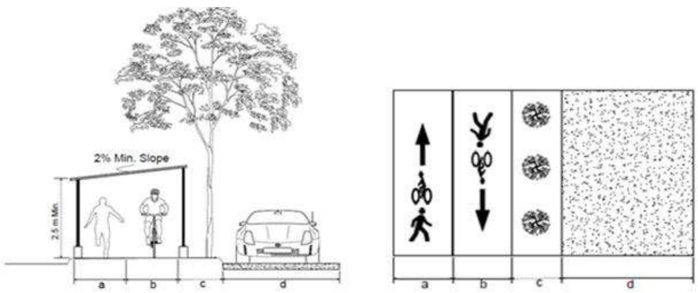


(a) (b)

Figure 4. Route for Each Type of Bicycle Infrastructure and Designed Bicycle Station Location Inside UPLB

Existing paths that are shared by NMT users and other modes can be seen near the main entrance gate of the University. While the existing shared roadway is indicated along the peripheral roads of the University, paths can be shared and utilized for both NMT and users of other modes. Figure 4b shows the location of the bicycle stations. The stations were placed within 500m distance from one to another. These are located beside the main buildings of the campus. The distance between stations is based on the results in the BNL model, where most distances that the respondents travel from one point to another are between 100m to 520m. The stations are placed 15m to 30m away from a building's main entrance for security purposes. The results of the survey showed that more than 69% of the respondents are willing to use a rental bicycle. Rental stations would be provided for those students who are willing to use the bicycle as their mode of transportation but cannot afford to have one. This is contrary to the BNL results where people are more likely to use NMT when it is free. Hence, studies may be conducted to determine the timeline where rental fees can be imposed. This is done in another study by Caponga *et al.,* (2021).

The proposed design of an NMT roadway facility was based on the result of road network inventory and factors in the logit method of analysis. The options for the NMT facility are shared paths, bicycle lanes, or roadways. The road network inventory was compared with the standards of AASHTO which means that the proposed design for the NMT facility would depend on its standards. Certain types of the facility would be inappropriate if the chosen path did not meet the said standard. Additionally, the roadway infrastructures needed to be built are based on the factors that affect the use of NMT. The design of the shared-use path and the bicycle lane was obtained by comparing the width values from the road network inventory and to the minimum standard of AASHTO. The significance of weather in the result of the BNL model was also accounted for in designing the shared-use path. The respondents tend to take other modes during hot and humid weather conditions as well as during rainy weather conditions. Having roofing in a pathway would allow the NMT users to travel during these weather conditions. The location of the shared use path can be seen in Figure 5.



SPECIFICATION FOR SHARED USE PATH

Line	Width a	Width b	Width c	Width d
1	1.8	1.2	1.5	5.8
2	1.5	1.5	1.5	VARIES

Figure 5. Elevation Plan and Top View for Design of Shared-Use Path (dimensions in meter)

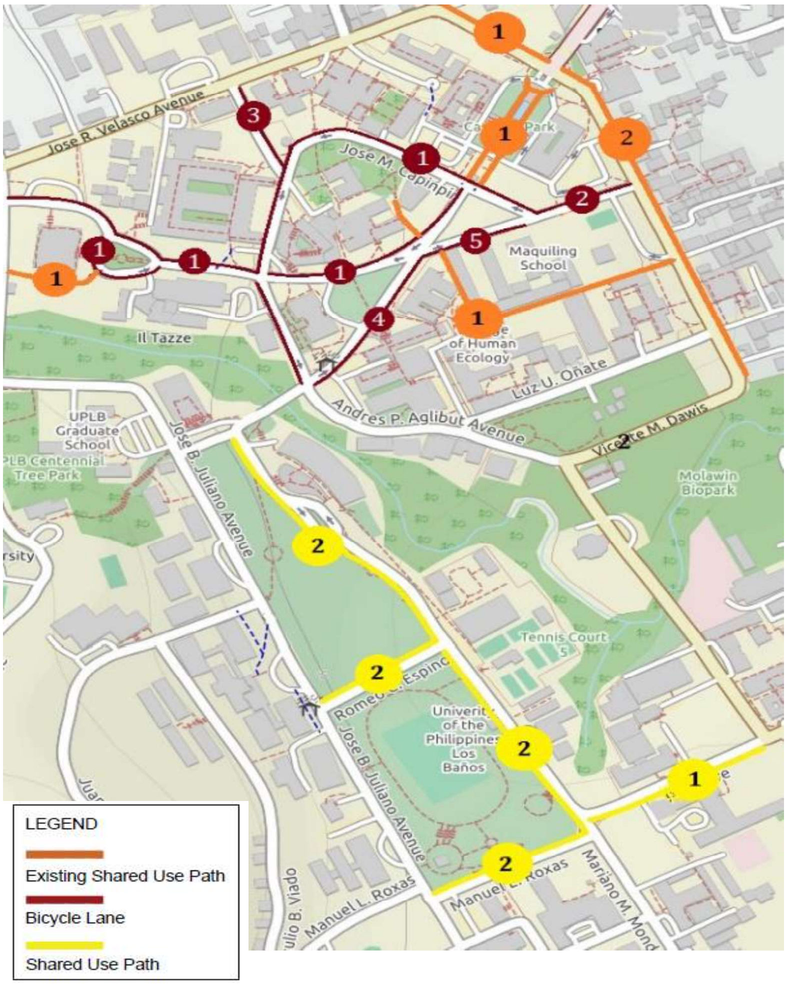
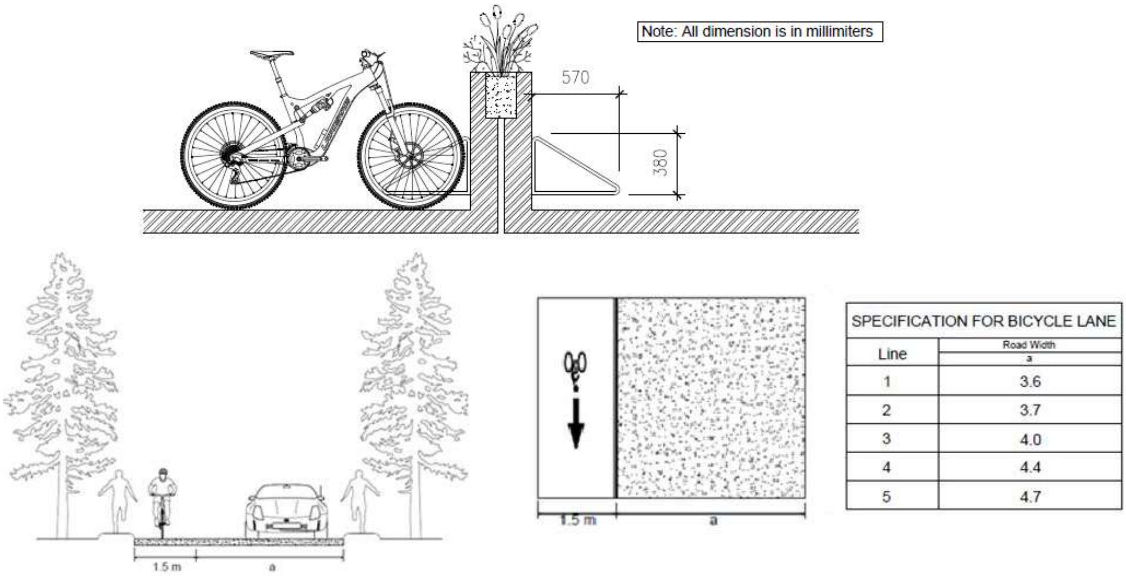


Figure 6. Route Design for Each Roadway Type



SPECIFICATION FOR BICYCLE LANE	
Line	Road Width a
1	3.6
2	3.7
3	4.0
4	4.4
5	4.7

Figure 7. Elevation Plan and Top View for Design of Bicycle Lane (dimensions in meter)

A single lane for bicycles is designed according to the traffic flow in the middle campus. Most of the roads in the middle campus are managed in a one-way direction. The location of bicycle lanes can be seen in Figure 6. The design for the bicycle stations was based on the standard design given in the AASHTO manual. There would be two different types of bicycle stations to distinguish if it is a rental station or parking station for bicycle owners shown in Figure 7 with details shown in Figure 8.

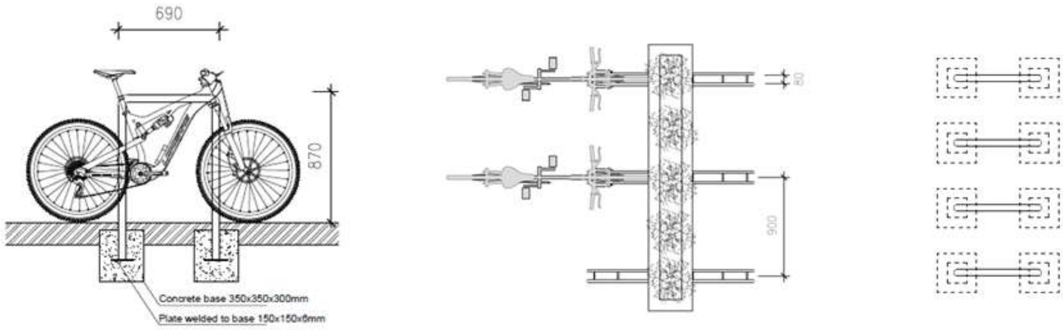


Figure 8. Design for Parking Station

5. CONCLUSIONS AND RECOMMENDATIONS

The objective of this study was to determine the factors that affect the use of NMT inside the university campus. In this study, the researchers identified 4 major factors that affect the use of NMT using the binary logit model. These factors include travel distance, travel time, rental facilities, and weather. Based on the results, it is logical to consider the effect of weather when people use NMT. The design of NMT infrastructure needs to have facilities such as covered lanes to keep people from being wet or from experiencing direct heat from the sun when using the facilities. In terms of shorter travel time and shorter distance travels, this would provide insight into the choice of NMT lanes to be included in the system. Rental facilities should also be carefully planned and designed.

The authorities of the university can help introduce and implement the use of NMT to help students have the leisure of commuting by bicycle or walking. As an example, this system was successfully used at the University of the Philippines Diliman. Although NMT facilities are costly, as a global strategy to decrease global warming and reduce greenhouse emissions, the authorities need to help finance NMT facilities in universities as a long-term beneficial project. Results show that majority of the students in the University of the Philippines Los Baños are willing to use NMT as their main mode of transportation if appropriate NMT facilities and infrastructures are provided. If possible, it is strongly recommended that the authorities provide these facilities and infrastructures since a lot of students are willing to use them. It is an effective way of promoting sustainable transportation, especially in the Philippines, where sustainable transportation is not so common. A lot of countries are promoting and implementing the use of NMT, so it is time to also do this in the Philippines. NMT users are more likely to use NMT facilities for free. Campus authorities can plan and consider schemes such as finding sponsors to make use of bicycles for free in the first 2 years; then put in minimal rental fees for succeeding years to come. Aside from weather conditions, which should be considered in the design of the NMT, the topography inside the university due to it being on a hilly site would be considered when building infrastructures for NMT. If addressed, this can encourage more NMT users on the campus.

Finally, the design for NMT facilities and infrastructure was proposed based on the road profile in UPLB, the minimum standard of AASHTO, and the result of the logit model. BNL model provided insights on the factors that are needed to be considered in designing the appropriate NMT facilities and infrastructure. Providing the necessary solution considering these factors would encourage more users to use NMT inside the campus. It is shown that more than 60% of the students were willing to use NMT as their mode of transportation if their university were provided with NMT facilities and infrastructure that would allow them to travel conveniently. Therefore, implementing the NMT system that was proposed in this study would encourage more students to use NMT around the campus as the researchers provided a solution based on the factors affecting their decision to use NMT.

Although this study highlights some factors that may affect the use of NMT, the number of observations was limited. For further studies and to have better insights, increasing the sample size may be needed. More data would allow more independent variables to be included in the binary logit model, hence more understanding of other factors that can be included in the NMT infrastructure design.

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