

# Evaluating the Impact of Factors on Young Cyclists' Intention of Aberrant Crossing at Intersections in China Based on Theory of Planned Behavior

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**Abstract-**This paper evaluated the impacts of various factors on the young cyclist's intention of aberrant crossing behaviors at intersections. Bicycles were classified into conventional bikes and electric bikes (hereinafter referred to as e-bikes). Data were collected from 374 participants in Nanjing, China. The hierarchical multiple linear regression analysis was conducted to estimate the impacts of various factor variables based on the theory of planned behavior (TPB). The results showed that three key traditional TPB variables including attitudes, subjective norm, perceived behavioral control (PBC) accounted for 50% of all variances in two scenarios plus the variables of past behavior with 3% of variance, conformity tendency in bikes scenario and anticipated affect with 1% of variance in e-bikes scenario constituting two modified TPB model. Three key traditional TPB variables resulted in an abundant increase of 42% of the variance in e-bikes, which is 6% higher than that in another scenario. The all selected predicting variables accounted for 66% of variance for e-bikes and 60% for bikes in predicting the crossing intentions. The findings of this study can help come up with interventions and education measures for aberrant crossing behaviors based on the effect analysis of variables on intention.

**KEYWORDS-** *aberrant crossing intention; Theory of Planned Behavior; variables; conventional bikes and electric bikes; comparison*

## I. INTRODUCTION

The problem of traffic congestion and air pollution from motor vehicles has raised growing concerns in urban transportation planning and management. As a complement to vehicular traffic, non-motorized travel modes (e.g. walking, cycling) have been promoted to better create a liveable and sustainable urban transportation system. Electric bike (e-bike), as a convenient and economical transportation mode, is often considered as a preferred choice among urban residents with respect to travel mode determination. Without the high expense of taxi and the low travel comfort experience of bicycle as well as some public transit modes, e-bikes possesses noticeable advantages in balancing individuals' mobility and accessibility patterns [1]. In addition, the usage of e-bikes could also bring some environmental

benefits. For instance, e-bikes were found to have a much lower polluting emission comparing to motorcycle and car [2]. Therefore, in the past few decades, there is a growing popularity of e-bikes usage especially among urban residents in cities with crowded population density. According to the information from China Bicycle Industry Information Center in 2013, the predicted ownership of e-bikes in China is about 130 million and the expected annual growth rate remains at 4 percent between 2013 and 2020.

Despite the fact that the increase in e-bike usage as a regular travel mode has brought considerable benefits from both individual and environmental prospects, the following consequences such as traffic operational influences (e.g. traffic chaos) and traffic safety impacts (e.g. e-bike accidents) deserve special attentions. The number of e-bike related fatalities and injuries has increased significantly over the past few years. Furthermore, fatalities and injuries of e-bikers accounted for 28.8% and 54.1% of the non-motorized traffic fatalities and injuries in China, 2010 [3,4]. Accident analysis revealed that over 60% of cyclists involving fatal crashes resulted from the violation of traffic rules, such as aberrant behaviors of running red light, speeding, overloading etc. In many cases, crashes between non-motor vehicles and vehicles often arise from cyclists' distracted decisions or risky behaviors during their road crossings processes. One typical violation behavior is that cyclists with either e-bikers (1) or bikers (2) (an example is shown in Fig.1) continue to run during red light phase at signalized intersections. Because of the ineffective enforcement of traffic laws and the weak safety awareness of traffic participants, violations in urban intersections are rather prevalent and become a research direction in traffic safety area.



Figure 1. Aberrant Behavior of E-bikes and Bikes at Intersection.

Previous studies have provided valuable insights into the internal characteristics of bicycle operations as well as the external factors that influence cyclists' riding behaviors. Plenty of researches have focused on examining factors that influence e-bikers' aberrant road crossing behaviors [5], including physical environment (e.g. road width, type of street, etc.), road user variables (e.g. demographic characteristics such as physiological and psychological factors) and e-bike elements (e.g. character of service, traffic characteristics).

In addition, some of these researches on the influencing factors of bikers' riding behaviors have been done in the last decades. And these researches could be generally divided into seven research topics: bikes and cyclists' characteristics, traffic flow, intersection control, capacity and level of service, geometric design etc. A detailed classification and illustration of these influence variables of e-bike studies can be derived from Taylor [6].

Further, massive conflicts caused by aberrant behavior of crossing between non-motor vehicles and vehicles were analyzed. Traffic conflicts techniques were used to estimate the safety effects of e-bikes and bikes and a comparison between them was conducted to judge if the conflicts from e-bikes were more likely to cause accidents [4].

These studies provide valuable insights in understanding the factor that possibly leading to the aberrant behavior of road crossing and afterwards conflict analysis caused by the violated behaviors of e-bikes and bikes cyclists in China. And more studies on riding behaviors were conducted through analyzing the influence factors of user behaviors' intention since these factors were found to be the primary determinant of traffic safety [7].

On the other hand, the relevant psychological factors are also needed to improve cyclists' safety. However, few research efforts have been contributed to estimate the aberrant riding behaviors and their associated psychological factors of cyclists.

One such model, the Theory of Planned Behavior (TPB) proposed by Ajzen has been widely adopted within the field of traffic safety [8]. And some well-known studies have applied TPB as the way of investigating and examining decision making in road crossing situations from psychological aspect of drivers and cyclists. With

regard to the traditional TPB, an individual's intention can be predictive of actual behavior when performing a particular manner and it is determined by one's attitude toward the behavior in question, subjective norms and perceived behavioral control (PBC). For example, in addition to the basic variables of TPB, newly discovered variables such as moral norms, anticipated regret, past behavior, self-identity and perceived susceptibility were applied to predict motorcyclists' intention to ride over the speed limit [9]. Yao and Wu identified risk factors affecting the accident involvement of e-bikers and established the relationships between safety attitude, risk perception, and aberrant riding behaviors [7]. Zhou set questionnaire to measure people's intentions when crossing an intersection in two road crossing situations, and their modified TPB model were consist of the attitude, subjective norms, PBC, anticipated affect, moral norms, and perceived risk [10].

However, few attempts have been made to relate aberrant behavior of crossing to potentially motivational variables through established theoretical TPB model. Further, few studies have assessed the predictive utility of the modified model with respect to aberrant crossing.

Given that most of previous studies have demonstrated the impact of additional variables on intentions and behavior, even after the traditional TPB variables have been taken into account the present study to test an extended TPB model [11]. For example, previous researches on the behaviors of driver and pedestrian also pointed out that several variables can be extended in the traditional TPB model. Several studies examined the difference of gender and age on pedestrians' behavior [12]. Cycling experience was also cited as one of the major influence factors, with a significant number of motorcycling accidents occurring within the first six months of motorcycle riding [13]. Chorlton identified a diversity of variables such as age and training status which were found to have an influence on motorcycle accident risk and severity [9].

Studies have shown that moral norm have an important influence on motorcyclists' decision to speed up when added to the prediction of speed intentions [14] and observed speeding behaviors [15]. Self-identity characterized by one's self-identification for safe behavior, has been shown to predict pedestrians' road crossing intentions and conformity tendency could emerge as the significant predictor of intention to road crossing for pedestrians [10]. Past behavior is typically the strongest predictor of intention and behavior, explaining variance over that accounted for by the TPB variables [16]. Perceived risk was measured by the statements [9]. Some studies have also examined the anticipated affect after having crossed the intersection as depicted by [17].

So far, little studies have applied the TPB to explore the impact of intentions on cyclists' behaviors with e-bikes or bikes of road crossing in China. Moreover, few researches have focused on cyclists' aberrant behaviors of road crossing at intersections. Therefore, this research is intended to fill this knowledge gap. The focus on young cyclists who are willing to have the aberrant behavior of road crossing is a concern, which is in line with the study from Shankar [18]. Therefore, the primary objectives of this study are as follows:

(1) extend the traditional TPB model on aberrant intention of crossing intersection for e-bikers and bikers given the increasing number of studies that have proved the impact of additional variables on intentions and integrate these different variables into the modified TPB model for scenarios in Nanjing, China.

(2) explain the extent to which the modified TPB model are impacted by demographic and other additional variables (i.e., conformity tendency, moral norm, anticipated affect, past behavior, self-identity, control belief etc.) on cyclists' road crossing intentions in each scenario.

(3) assess the predictive utility of the modified model in both scenarios and analyze the comparative effect of the modified TPB model and impacts of factor variables are compared between e-bikes and bikes situation.

## II. DATA COLLECTION

### A. Participants

A total number of 344 cyclists, aged from 18-30 years old, responded to the survey. All participants were selected from the urban residents dwelling at the central areas in Nanjing. The samples were approximately balanced by gender on the whole. A pre-designed questionnaire was delivered to each participant at a public place such as a supermarket or a fast food restaurant. So the sample randomly selected from resident cyclists group in Nanjing. All participants were asked to read an introduction about the research and the format of the questionnaires before filling in the items. And an informed consent form was also assigned to each participant to ensure information security and privacy protection. Respondents were ensured that participants were voluntary and their responses would be valid for the later analysis. In addition 18 questionnaires were excluded for the analysis because they did not answer the items in questionnaires completely.

### B. Questionnaire

Generally, electric bikes can be divided into two categories: scooter style electric bikes (SSEB) and bicycle style electric bikes (BSEB) [19]. But two cycling modes were generated in this study: one was cycling e-bikes including above two categories, and the other was cycling bikes.

In the questionnaire, participants would like to rate on 7-point Likert Scales, including depiction of the likelihood degree that they would cross intersection with aberrant behaviors in two situations. Meanwhile, the perceived degree of aberrant road crossing in two situations was obtained from some question items, thus to get their overall rating of each item selected.

Participants in the study were asked to fill out a questionnaire selecting one from two modes: e-bikes and bikes scenario. Then participants completed to a series of items constructed (e.g., age, gender, etc.), then standard TPB variables (attitude, subjective norm, PBC) and additional variables (anticipated affect, control belief, etc.) consisted of items in questionnaires. The dimensions number of factors categorized by items in this research was eleven satisfied to anticipated result and at last toward the stabilization on this number. Finally this paper included six additional variables: control belief, moral

norms, anticipated affect, past behavior, self-identity and perceived risk, conformity tendency.

## III. METHOD

Exploratory Factor Analysis (EFA) method was used to find the underlying dimensions that influenced the questionnaire variables. The EFA process adopted the principal component and varimax rotation approach. First of all, the collected data should be distinguished whether to have a factor analysis using Kaiser-Meyer-Olkin and Bartlett's spherical inspection coefficient. Then factor analysis would be carried out when the coefficient was more than 0.70 [20].

The research also needed to conduct the reliability and validity analysis to ensure the responsibility of questionnaires and quality of items. Generally Cronbach's alpha, a coefficient of consistency that measured the homogeneity of items in a dimension, was used to evaluate the reliability and internal consistency. Following Nunnally's criteria, alpha values equal to or exceed 0.7 indicated the acceptable reliability [21].

Validity was used to measure the difference degree between result and the anticipated goal. Then validity was analyzed by using the criterions listed as follows: (1) loading value of each item on the common factor that was at least more than 0.40; (2) each item did not exist the crossing-loading, namely two or more loading value with more than 0.40 on one common factor was invalid; (3) degree of communality was not less than 0.16. The items that did not satisfy the three criterions were rejected through screening analysis from several steps.

## IV. RESULT

A series of hierarchical multiple linear regression analyses were applied to assess the contribution of variables for each scenario. It was likely to analyze the predictive utility of each variable after controlling other influence variables from table 1.

Considering e-bike situation, in Step (1), age, gender, marital status and independent children account for 9% of the variance in behavioral intentions ( $F$ -change(4,166) = 4.06,  $p < 0.001$ ), with all four variables emerging as significant predictors. In Step (2), riding variables account for an additional 10% of the variance in intentions ( $F$ -change(5,161) = 7.98,  $p < 0.001$ ), with all five variables emerging as significant predictors. In Step (3), the traditional TPB variables, when added to the regression analysis, account for an additional 42% of variance, resulting in a substantial and significant increment to 61% in intention ( $F$ -change(3,158) = 65.37,  $p < 0.001$ ), with three TPB variables emerging as significant predictors along with demographic and riding variables. In Step (4), the extended traditional TPB variables only account for an additional 2% of variance in road crossing intention ( $F$ -change(1,157) = 69.86,  $p < 0.05$ ). In Step (5), the five extended TPB variables only account for an additional 3% of the variance in intention ( $F$ -change(5,152) = 72.38,  $p < 0.05$ ), so that all five extended variables emerging as slightly significant predictors. In Step (6), extended variables of anticipated affect account for an additional 1% of variance in intention ( $F$ -change(1,151) = 75.43,  $p < 0.05$ ), with anticipated affect having a small but statistically significant independent effect along with others' variables.

For bike situation, in Step (1), age, gender, marital status and independent children account for 4% of the variance in behavioral intentions (F-change(4, 168) = 1.91,  $p > 0.05$ ), with all three variables emerging as insignificant predictors. In Step (2), riding variables account for an additional 6% of the variance in intention (F-change(5, 163) = 4.03,  $p < 0.05$ ), with all five variables emerging as slightly significant predictors. In Step (3), the traditional TPB variables, when added to the regression analysis, account for an additional 36% of the variance, resulting in increment to 46% in intention (F-change(3, 160) = 39.65,  $p < 0.001$ ), with three TPB variables emerging as most significant predictors. In Step

(4), the extended traditional TPB variables account for an additional 2% of the variance in intention (F-change(1, 159) = 44.94,  $p < 0.05$ ). In Step (5), the five extended TPB variables account for an additional 9% of the variance in intention (F-change(5, 154) = 50.98,  $p < 0.001$ ), so that all five extended variables emerging as significant predictors than five variables in another situation. In Step (6), extended variables of anticipated affect account for an additional 3% of the variance in intention (F-change(1, 153) = 63.27,  $p < 0.001$ ), with past behavior having a relatively large but statistically significant effect along with others' variables.

TABLE 1. Regression Analysis to Predict Intentions in E-bikes (N = 171) and Bikes (N = 173) Scenario

Step	Predictor	R <sup>2</sup>	ΔR <sup>2</sup>	F	Step 1	Step 2	Step 3	Step 4	Step 5	Step 6
<i>E-bikes</i>										
1.	Gender	.09	.09	4.06	.00	-.05	.02	.02	.02	.01
	Age				.09	.16	.13	.11	.08	.08
	Marital status				-.17	-.18	-.06	-.03	-.05	-.05
	Dependent children				.44***	.38***	.19*	.15	.18**	.19**
2.	Frequency	.19	.10	7.98		-.11	.01	.02	.03	.05
	Riding Experience					-.04	-.02	-.03	-.01	-.01
	Accident history					-.20**	-.05	-.06	-.10	-.09
	License status					.17**	.10	.10	.10	.09
	Driving Experience					-.10	.04	.06	.06	.07
3.	Attitude.	.61	.42	65.37			.33***	.31***	.26***	.26***
	Subjective norm						.32***	.31***	.21***	.21***
	Perceived behavioral control						.23***	.20**	.16**	.15*
4.	Control belief	.62	.01	69.86				.13**	.12*	.12
5.	Moral norm	.65	.03	72.38					-.04	-.04
	Past behavior								.17**	.09
	Perceived risk								-.08	-.08
	Self-identity								-.00	.01
	Conformity tendency								.13*	.11
6.	Anticipated affect	.66	.01	75.43						.14*
<i>Bikes</i>										
1.	Gender	.04	.04	1.91	-.08	-.06	-.02	-.04	.01	.02
	Age				.16	.16	.12	.13	.06	.08
	Marital status				.13	.22	.17	.15	.07	.09
	Dependent children				.13	.10	-.04	-.02	-.06	-.09
2.	Frequency	.10	.06	4.03		.11	.11	.10	.14*	.13*
	Riding Experience					.05	.02	.01	.02	-.03
	Accident history					-.20**	-.08	-.07	-.02	-.02
	License status					-.04	-.06	-.07	-.12*	-.10
	Driving Experience					-.08	-.12	-.12	-.17**	-.14*
3.	Attitude.	.46	.36	39.65			.37***	.32***	.25***	.21***
	Subjective norm						.23***	.17***	.15***	.13***
	Perceived behavioral control						.28***	.24***	.21**	.20***
4.	Control belief	.48	.02	44.94				.15***	.13**	.10
5.	Moral norm	.57	.09	50.98					-.15*	-.12
	Anticipated affect								.11	.07
	Perceived risk								.01	-.04
	Self-identity								-.02	-.01
	Conformity tendency								.26***	.18***
.6	Past behavior	.60	.03	63.27						.26***

Note: All correlation coefficients is \*\*\* $p < 0.001$ , \*\* $p < 0.01$ , \* $p < 0.05$ .

## V. DISCUSSION

The results demonstrate that all predictor variables accounts for 66% in e-bikes and 60% in bikes scenario of the variance in predicting intentions which is consistent with reviews of the TPB with even taking account of additional variables remaining below 50% on average [10].

### A. Support for the traditional TPB variables

In general, the findings indicate strongly supports for the application of the TPB to cyclists' intention. In line with previous studies [17], the overall results illustrate the usefulness of attitude, subjective norm and PBC as significant predictors of behavioral intention in both scenarios.

The standardized beta weights of three traditional TPB variables were positive for all models and demonstrated that as attitudes and subjective norms regarding the crossing behavior become more positive and PBC increased, people are more likely to present stronger intentions to cross the intersection. As can be seen from the models in both situations, these basic traditional TPB variables are generally far more important predictors and they accounted for more than 50% of the change variance, in accordance with the study [9].

### B. No support for the extended traditional TPB variables

Analysis variable of PBC highlights in bikes than e-bikes situation when the control belief does not enter or enter the regression model. Yet control belief with low coefficient does not emerge as significant predictor in both situations. Hence it means that control belief has not effect on the contribution of PBC in the regression model, which represents PBC and control beliefs not emerging as significant predictors simultaneously is in line with the study [9].

### C. Support for the extended TPB variables constituting the modified TPB model

In line with Zhou's study, moral norm is not a significant predictor of crossing intentions [10]. Anticipated affect, emerges as a significant predictor for road crossing intention in e-bikes situation, while it is not of such significance in bikes situation. This result could possibly arise from the fact that e-bikes own the feature of traveling at a faster speed than bikes leading to more potential opportunities to cross the intersection. Thus, e-bikers focus on the expressive anticipated feelings so as to decide whether or not to violate the traffic regulations in road crossing processes. And Lin demonstrated that the mean operating speed of e-bikes was found to be 47.6% higher than that of bikes [22]. So the speed difference between e-bikes and bikes may be the discriminative factor variables to the different modified model.

Indeed, evidence regarding the predictive utility of perceived risk has been somewhat mixed through a broader literature. The result is inconsistent with Chorlton's study in that perceived risk is not a significant predictor for two situations in our study [9]. There are possibly underlying factors, such as optimistic bias or unrealistic optimism related to the idea that individual rider felt less risk than others are to increase disease or danger [23]. Thus perceived risk may not have effect on intentions if

the relevant risk is not understood. The finding is identical to study from Norman's study [17]. In contrast to the study by Chorlton, past behavior is significant for predicting intention to road crossing when added to other variables and it is the most important variable among the extended variables in bikes situation [9]. However, past behavior cannot be regarded as a significant variable, though it can be emerged as a significant predictor when anticipated affect did not enter the model in e-bikes situation.

Therefore, results from this study along with findings from previous studies, suggest that past behavior and anticipated affect may be a significant predictor for road crossing intentions in different scenario and perceived risk, self-identity, moral norm may require more investigation. Conformity tendency is a significant predictor for bikes situation, not for e-bikes situation. It is also possible that other factors, given individual bikers with a tendency towards conformity would be more likely to behave in a manner that is consistent with other individuals. In that case, bikers could have a feeling of safety among the large riding crowd and have fewer moral pressures to offset the characteristic of slower speed of bikes.

### D. Support partly for the demographic and riding characteristics variables

It is interesting to note that demographic variables such as gender, age, etc. and riding variables such as riding frequency and experience, etc. generally failed to add to the predicting intentions. This is not surprising for that age tends to be an insignificant predictor in both scenarios, even if previous works have documented a clear contribution of age and sex to predicting intentions. This is because dividing group about age variable is not involved in this research that result in the unobvious distribution of age. Gender variable does not emerge as the important predictor which is in line with the study discussion [9, 10]. The variable of independent children emerges as a significant predictor in e-bikes scenario. This simple correlation relationship is also demonstrated in another scenario.

## VI. CONCLUSIONS

In the present study, intentions to aberrant road crossing in e-bikes and bikes scenarios are examined and analyzed using a questionnaire survey based on the TPB. This research examined the factors of cyclists' intentions to engage in aberrant crossing behavior and established the relationships between demographic, traditional TPB, extended traditional and extended TPB variables, thus came into being the modified TPB model. Then this study had a comparison for the modified model between different situations and impacts of variables were analyzed and compared between e-bikes and bikes scenario.

The result of regression on intention supports the inclusion of the traditional variables in both scenarios plus past behavior in bikes, anticipated affect and conformity tendency in e-bikes situation as the significant predictors. All predictor variables accounts for 66% (e-bikes) and 60% (bikes) of variance in predicting intentions. On the whole, the results also suggest that three traditional TPB

variables has similar effect between two scenarios and they are accounted for over 50% of all variance in each scenario, however, the addition of traditional TPB variables resulted in an abundant increase of 42% variance for e-bikes scenario than the increase of 36% variance in another scenario. Then past behavior in bike scenario was able to explain significantly greater amount of 3% variance than anticipated affect with 1% variance in intention of violation, which shows the extended TPB variables are able to mediate the influence brought by traditional TPB variables.

The findings of the present study give strong supports for the TPB's application to cyclists' intentions to roadcrossing by violating the traffic rules, and it is feasible that the changes of crossing intentions are closely associated with attitudes, subjective norms, PBC and anticipated affect or past behavior. Therefore those components focused could make cyclist's safety interventions most effective rather than simply test their utility of model. Based on the results of study, interventions and education measures in order to change intention in different situations should be carried out as follows. The strategies are that (1) making most e-bikers know the speed limit and expected maximum speed of e-bikes regulated by law in urban area to prevent cyclists more anticipated intention of aberrant road crossing (2) focusing on conformity tendency for bikes situations, it could be conducive to educate young cyclists to know that conformity tendency by violating the traffic rules may leads to risky behaviors (3) making bikers to control the effect brought by past behavior by means of safety interventions and educations.

Thus the present findings would indicate a good level of prediction of intentions across scenarios. Furthermore, there are also a number of works needed to the future researches: (1) to construct TPB models in two situations could be focused on observing actual behavior; (2) more qualitative questionnaires should be surveyed and analyzed to enrich TPB model; (3) the power of extended variables to influence traditional TPB in modified model needs to be tested in this riding domain.

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