# Elasticity Analysis for Social Interactions: A Case of Scooter and Bicycle Parking Behavior in Taiwan

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The effect of social interactions on individual behavior are apparent in many travel-related phenomena. However, previous travel behavior models often assume that individual behavior is independent of the behavior of others, which results in a biased evaluation of transport policy. Thus, this study examines on-street scooter and bicycle parking in Tainan city center, Taiwan. A stated preference questionnaire survey of scooter and bicycle users (192 persons) is performed by face-to-face interview. Through the collected data, the parking location choice behavior model incorporating social utility is built. Based on this, a modified method of elasticity analysis for social interactions is proposed in this study. The estimation results of the model show that the average choice level of group has a significant positive effect on individual decision, which indicates that the users tend to conform to the behavior of others in terms of parking location choice. Then policy evaluation is performed by the modified elasticity analysis method and compared with by the traditional one. First, based on a traditional evaluation method which is often employed in previous studies, the percentage change in the probability of individual choosing off-street parking would be 0.81% given that the distance (from the parking lot to the destination) decreases by 1%, whereas, under the same condition, the percentage change in the probability would be 3.38% according to the proposed method incorporating the chain effect of social interactions. Secondly, based on the traditional evaluation method, the percentage change in the probability of individual choosing off-street parking would be 1.76% given that the fixed cost (of using the parking lot each time) decreases by 1%, whereas, under the same condition, the percentage change in the probability would be 7.33% according to the proposed method. This study reveals that under social interactions the biases in policy evaluation can be corrected.

***Key Words :*** *scooter and bicycle parking, social interactions, chain effect of social interactions, elasticity analysis*

## 1. INTRODUCTION

Scooter and bicycle in Taiwan have played important roles of mobility, and the amount have largely increased. In consequence, scooter and bicycle have caused many severe issues which are specific to Taiwan[1)]. However, urban planning and urban transportation planning in Taiwan paid little attention to proposing corresponding solutions. For instance, on-street parking in city centers often leads to a condition in which sidewalks and arcades originally offered walking in amenity for pedestrians are occupied with scooters and bicycles. The disorder on-street scooter and bicycle parking has not merely impeded pedestrian movement, but led the traffic on roads to be chaotic and unsafe.

Aiming at the improvement of on-street scooter and bicycle parking in city centers in Taiwan, past studies often build discrete choice models to explore the effects of socio-economic attributes and policy variables on parking behavior. Based on this, elasticity analyses can be conducted to underlie parking policy intervention. However, such studies cannot consider the "invariants of human behavior" [2)] that probably exist in transportation phenomena. On the contrary, the progression of various fields in social science in many ways is based on the pursuit of the invariants, for example, the improvement of rationality in economics and sociology, as well as the exploration of psychological and behavioral theory in cognitive psychology and social psychology[3)]. Therefore, only if the invariants are grasped, can research on travel behavior including parking behavior make better human-oriented policy.

Following the context of the pursuit of invariants, more and more studies on travel behavior have respected the effect of psychological factors[4]. When psychological factors are incorporated into analysis, the decision-making of agents in models hinges on not merely substantial payoffs but utilities referring to emotions and consideration for others (a concept of the transition from payoffs to utilities[5]). Among these, deriving from the thought of utilities decided by others, the behavior of conformity with reference group has been concerned. In this occasion, people received the effect of "social interactions." [6),7] In transportation field, such social interaction influence probably occurs in chaotic bicycle parking on sidewalks, illegal car parking, excessive car use, and disapproval of road pricing[8]. Hence, if the proposition of transport policy is based on the evaluation deriving directly, through summation, from the behavior of individuals, the social or transport phenomena is just regarded as an case of isolated society, but more often this is not so[9]. Contrarily, if the effect of social interactions is measured and further incorporated into policy evaluation, the implied assumption that individual behavior is independent of others can be excluded in travel behavior research, and thereby more approach the invariants of human behavior.

In light of the above description, this study examines on-street motorcycle and bicycle parking. The city center of Tainan City, Taiwan, is designated as the study area. A stated preference questionnaire survey of motorcycle and bicycle users was performed by face-to-face interview. Through the collected data, this study intends to achieve a two-fold purpose. (a) First, build a parking location choice behavior model considering social interactions to confirm the determinants of the behavior, including whether the effect of social interactions exists among scoter and bicycle users. (b) Modify the elasticity analysis method in the framework of discrete choice model to incorporate the effect of social interactions into policy evaluation.

## 2. LITERATURE REVIEW

### (1) Definition and category of social interactions

Over the few decades, quantitative analyses on "social interactions" representing the nonmarket interactions among individuals[10] have greatly developed in many fields of social science. It is on account of receiving impacts from the domains of social psychology, sociology, economics, etc.

In the field of sociology, the threshold model has been presented to describe the formation of social situations, in which people make the same behavioral decision in the group as a result that the numbers of other members taking the action have achieved the individual's threshold of taking action[11]. In the field of sociological psychology, the conformity and peer effects are addressed to interpret how individuals in a group follow other members' behavior, some of which they do not even approve in their minds[12]. In the field of Economics, social interactions refer to that individual's received utility or payoff from adopting an action is partly decided by other members' action in her/his reference group[6),7]. The related concept also consists in the literature discussing bandwagon effects[13], network externalities[14], and spillover effects[15),16].

The existence of social interactions could be derived from two types as follows: (a) Informational social influence. It happens when an individual desires to obtain additional information from other members in the group in order to avoid uncertainty or difficulty to help themselves make decision. This influence makes individuals have the conversion to conform as the result of a private acceptance of others' behavior[17)-19]. (b) Normative social influence. It happens when an individual takes the action mainly aiming to gain the acceptance, or avoid the expulsion of other members of a group (even a group composed of strangers[20]). The influence makes individuals have a public compliance with group norms and behavior but probably without a private acceptance of it[19),21)-23].

In the reception of the above-mentioned impact, the transportation research community has begun to examine the role of social interactions and its relationship with travel and transportation with rapid progression[24]. Comparing to past studies based on the traditional choice modeling approach[25] with the assumption that each individual's behavior is independent of each other, the studies concerning the social influence/contact/context effects lead to a more behaviorally realistic representation of decision-making process[26]. As a consequence, such studies promise to generate a more refined understanding of transportation processes in the relatively short term, and also the models and techniques used to analyze transportation systems, travel behavior, and to support planning practice in the medium term[24].

### (2) Transportation and social interaction research

"The principal task of the social sciences lies in the explanation of social phenomena, not the behavior of single individuals. In isolated cases the social phenomena may derive directly, through summation, from the behavior of individuals, but more often this is not so." (Coleman, 1990, p. 2)[9]

In order to avoid such fallacy of summation, several studies in transportation and travel research field have considered interaction effects on certain issues. For instance, Kobayashi, Kita, and Tatano[27] presented a random matching model for within-family joint trips production between two members by incorporating economic, altruistic, and paternalistic motives. The study just belongs to the scope of intra-household interactions. Going beyond this, Morikawa, Tanaka, and Ogino[28] formulated a binary logit model in which the utility level of the other members is incorporated into the utility function of decision makers applied to the voluntary restriction of car use. Jakobsson, Fujii, and Gärling[29] investigated determinants of private car users' acceptance of road pricing and found the effect of anticipated social pressure to reduce car use. Sasaki, Nishii, and Tsuchiya[30] focused on the interaction between individual decision-making and macroscopic participating rate for P&BR (park and bus ride), and used assumed individual response to aggregate rate of using P&BR to simulate the collective behavior. Hsieh, Hsia, and Yeh[1] analyzed the individuals' parking location choice given the proportion of on-street scooter and bicycle parking, and measured the effect of taking into account the own on-street parking's impact on others. Belgiawan, Schmöcker, and Fujii[31] analyzed the correlation of four groups constructed by principal component analysis, including friends, commercial, siblings, and parents, with the desire to purchase a different car. However, the studies similar to the above mention pay little attention to the formation of collective behavior based on micro-individual behavior influenced by social interactions.

In addition, a few studies have applied the discrete choice approaches incorporating the social utility term that is developed by Brock and Durlauf[6),7] to capture the global interactions, and subsequently adapted for local interactions by Dugundji and Gulyas[32),33], in which the probability of an individual's choice is proportional to the aggregate choice behavior of the reference group and the relevant social network. For example, regarding global interactions, Fukuda and Morichi[8] studied the illicit bicycle parking behavior in three areas where the field effect is determined by average choice level of individual's reference group composed of other people parking near the train station in which the individual parks. Additionally, it figured out the equilibrium states of collective behavior and proposed the matched policy intervention performed by police patrols. In contrast, for local interactions, Páez and Scott[34] used simulated data to study telecommute behavior for a range of networks of different sizes defined by a similarity on a two-dimensional matrix of personal characteristics. Subsequently, Páez, Scott, and Volz[35] presented a multinomial logit model of residential location choice by using simulated network data with varying degrees of distributions and clustering parameters. Although these studies pay more attention to the formation of collective behavior based on individuals with social interactions.

Therefore, this study refers to the methodology of social interactions presented by Brcok and Durlauf[6),7] to build the model to describe the scooter and bicycle parking location choice. Furthermore, because the previous studies have not provide a precise method to conduct the policy evaluation under social interactions, this study also propose a modified method of elasticity analysis in the framework of discrete choice models.

## 3. MODELING APPROACH

The modeling approach contains three parts. The first and the second part refer to the binary choice model and its specification. The modeling presented by Brock and Durlauf[6),7] can deal with the examination of social interactions by incorporating social utility. The third part refers to a modified elasticity analysis method proposed by this study in order to evaluate the policy impact within the chain effect of social interactions. This new method can be integrated in the framework of discrete choice models.

### (1) Binary choice model incorporating social utility

This study treats "global interaction" as basic framework of social interaction. In addition, the random utility theory is considered. Therefore, the individual decision-making incorporates the concern of social utility that could be used to reflect social interactions besides private utility.

First of all, a binary behavior of an individual $i$ is coded into the binary variable $w_i$, which takes a value equal to 1 if an individual chooses alternative A, and -1 if an individual chooses alternative B. The total indirect utility of an individual $i$, for his/her behavior $w_i$, coded by $V(w_i)$, is assumed to be divided into three components: (a) observable private utility $u(w_i)$, (b) social utility $S(w_i, \overline{m}_i^e)$, and (c) unobserved random utility $\varepsilon(w_i)$. Accordingly, $V(w_i)$ is written as:

$$V(w_i) = u(w_i) + S(w_i, \overline{m}_i^e) + \varepsilon(w_i) \tag{1}$$

where $\overline{m}_i^e$ in terms of social utility signifies the subjective expected value of average choice in the population of individual $i$. According to the definition of $w_i$, the range of $\overline{m}_i^e$ is between -1 and 1.

In order to embody a multiplicative interaction between individual and expected average choices, the social utility is written as:

$$S(w_i, \overline{m}_i^e) = J w_i \overline{m}_i^e \tag{2}$$

Given the assumption that $\varepsilon(w_i)$ is IID Gumbel distributed, individual choice probability for either alternative based on binary logit model incorporating the subjective expected value of average choice in the population $\bar{m}_i^e$ can be derived as:

$$\mathrm{Prob}(w_i) = \frac{\exp[\theta(u(w_i) + Jw_i\bar{m}_i^e)]}{\sum_{v_i\in\{+1,-1\}}\exp[\theta(u(v_i) + Jv_i\bar{m}_i^e)]} \tag{3}$$

**(2) Econometric specification**

Through econometric specification of the above model, the existence of social interaction as well as the entire model can be tested statistically. In the process of specification, the identification problem of parameters for confirming social interactions[10),36),37)] needed to be resolved to distinguish between the endogenous effect (originated from social interactions) and the exogenous effect.

First of all, the deterministic private utility $h_i$ which can reflect the heterogeneity across individuals is assumed in a linear-in parameter specification as:

$$h_i = b + \boldsymbol{c'X}_i + \boldsymbol{d'Y} \tag{4}$$

where $\boldsymbol{X}_i$ is a column vector of individual-specific variables, $\boldsymbol{Y}$ is a column vector of reference-group-specific variables (as the variables of policy), $b$ is a constant of unknown parameter, and $\boldsymbol{c'}$ and $\boldsymbol{d'}$ are corresponding column vectors of unknown parameters.

Concerning the identifiability of parameters, the scale parameter for random utility term is set to equal to 1 through normalization[7)]. In addition, through introducing the assumption of rational expectation[6),7)], the $\bar{m}_i^e$ can be replaced by $\bar{m}^e$. Thus, incorporating Eq. (4), the binary choice model for individual $i$ can be rewritten from Eq. (3) as:

$$\mathrm{Prob}(w_i) = \frac{\exp[w_i(b + \boldsymbol{c'X}_i + \boldsymbol{d'Y} + J\bar{m}^e)]}{\sum_{v_i\in\{+1,-1\}}\exp[v_i(b + \boldsymbol{c'X}_i + \boldsymbol{d'Y} + J\bar{m}^e)]} \tag{5}$$

The unknown parameters ($b$, $\boldsymbol{c}'$, $\boldsymbol{d}'$, $J$) can be obtained using maximum likelihood estimation. The log-likelihood function is constructed as:

$$LL = \sum_i \ln \mathrm{Prob}(w_i)$$

$$= \sum_i \ln\left\{\frac{\exp[w_i(b + \boldsymbol{c'X}_i + \boldsymbol{d'Y} + J\bar{m}^e)]}{\sum_{v_i\in\{+1,-1\}}\exp[V_i(b + \boldsymbol{c'X}_i + \boldsymbol{d'Y} + J\bar{m}^e)]}\right\} \tag{6}$$

If $J \neq 0$, there is the endogenous effect in target behavior. If $\boldsymbol{d} \neq 0$, on the other hand, there is the exogenous effect.

**(3) Elasticity analysis considering the chain effect of social interactions**

In the framework of discrete choice models, elasticity analysis is often used to evaluate the impact of policy. In this method, individual elasticity refers to the response of the choice probability of individual, whereas aggregate elasticity refers to the response of the population[25)]. Aiming to explore the effect of the policy variables on target behavior, and the comparison of sensitivity between the policy variables, the aggregate elasticity ($E_{y_{Ak}}^{\bar{P}_A}$) is often calculated as below:

$$E_{y_{Ak}}^{\bar{P}_A} = \frac{\sum_{i=1}^N P_{Ai}\cdot E_{y_{Aik}}^{P_{Ai}}}{\sum_{i=1}^N P_{Ai}}$$

$$E_{y_{Aik}}^{P_{Ai}} = \frac{\partial P_{Ai}}{\partial y_{Aik}}\cdot\frac{y_{Aik}}{P_{Ai}} = (1 - P_{Ai})\cdot y_{Aik}\cdot d_k \tag{7}$$

where $E_{y_{Aik}}^{P_{Ai}}$ is individual elasticity, $P_{Ai}$ is the choice probability of alternative A for individual $i$, $y_{Aik}$ is the value of the k-th policy variable in alternative A for individual $i$, and $d_k$ is the value of coefficient of the k-th policy variable.

However, if social interactions exist among individuals, the above formula derived from the traditional elasticity analysis cannot evaluate the final impact of policy. In order to conduct policy evaluation under social interactions, the following processes need to be considered.

(a) Initially, policy intervention brings change in average choice level of population.

(b) Subsequently, the changed part in average choice level of population triggered by policy will turn to drive a specific proportion of individuals (according to the strength of social interaction) to conform.

(c) In the meantime, the conforming part will turn to drive a specific proportion of individuals to conform, and this process will repeat until the effects converge when the conforming part can not drive any others to conform.

It is needed to incorporate the processes into the traditional elasticity analysis in order to accurately evaluate effects of policy under social interactions. Therefore, this study attempt to decompose "final impact of policy" into two parts. First, process (a) is regarded as "① direct effect of policy" that is equal to aggregate elasticity of policy variable (= $E_{y_{Ak}}^{\bar{P}_A}$). Second, processes (b) and (c) are regarded as "② chain effect of social interactions" that the traditional elasticity analysis is not capable of covering (assumed as $SE_{\bar{m}_A^e}^{\bar{P}_A}$). The relationship between them can be constructed as (below the elasticities return the absolute values in order to eliminate the influence of the signs of variables):

$$FE_{y_{Ak}}^{\bar{P}_A} = \left|E_{y_{Ak}}^{\bar{P}_A}\right| + SE_{\bar{m}_A^e}^{\bar{P}_A}$$

$$= \left|E_{y_{Ak}}^{\bar{P}_A}\right| + \left(\left|E_{y_{Ak}}^{\bar{P}_A}\right|\right)\cdot\left|E_{\bar{m}_A^e}^{\bar{P}_A}\right| + \left(\left|E_{y_{Ak}}^{\bar{P}_A}\right|\cdot\left|E_{\bar{m}_A^e}^{\bar{P}_A}\right|\right)\cdot\left|E_{\bar{m}_A^e}^{\bar{P}_A}\right| + \left[\left(\left|E_{y_{Ak}}^{\bar{P}_A}\right|\cdot\left|E_{\bar{m}_A^e}^{\bar{P}_A}\right|\right)\cdot\left|E_{\bar{m}_A^e}^{\bar{P}_A}\right|\right]\cdot\left|E_{\bar{m}_A^e}^{\bar{P}_A}\right| + \cdots\cdots + \left[\left(\left|E_{y_{Ak}}^{\bar{P}_A}\right|\cdot\left|E_{\bar{m}_A^e}^{\bar{P}_A}\right|^{n-1}\right)\right]\cdot\left|E_{\bar{m}_A^e}^{\bar{P}_A}\right|$$

$$= \left|E_{y_{Ak}}^{\bar{P}_A}\right|\left(1 + \left|E_{\bar{m}_A^e}^{\bar{P}_A}\right| + \left|E_{\bar{m}_A^e}^{\bar{P}_A}\right|^2 + \left|E_{\bar{m}_A^e}^{\bar{P}_A}\right|^3 + \cdots + \left|E_{\bar{m}_A^e}^{\bar{P}_A}\right|^n\right),$$

$$n \to +\infty$$

$$= \left|E_{y_{Ak}}^{\bar{P}_A}\right| \left( \frac{1-\left|E_{\bar{m}_A^e}^{\bar{P}_A}\right|^n}{1-\left|E_{\bar{m}_A^e}^{\bar{P}_A}\right|} \right) \quad (8)$$

where $E_{\bar{m}_A^e}^{\bar{P}_A}$ is the aggregate elasticity of average choice level of population ($\bar{m}^e$). It can be calculated as:

$$E_{\bar{m}_A^e}^{\bar{P}_A} = \frac{\sum_{i=1}^{N} P_{Ai} \cdot E_{\bar{m}_{Ai}^e}^{P_{Ai}}}{\sum_{i=1}^{N} P_{Ai}},$$

$$E_{\bar{m}_{Ai}^e}^{P_{Ai}} = \frac{\partial P_{Ai}}{\partial \bar{m}_{Ai}^e} \cdot \frac{\partial \bar{m}_{Ai}^e}{P_{Ai}} = (1 - P_{Ai}) \cdot \bar{m}_{Ai}^e \cdot J \quad (9)$$

where $E_{\bar{m}_{Ai}^e}^{P_{Ai}}$ is individual elasticity, $\bar{m}_{Ai}^e$ is the value of the variable "average choice level of population" (assumed to be assigned to alternative A), and $J$ is the coefficient of "average choice level of population." In general social phenomena, it is reasonable to assume $0 \le \left|E_{\bar{m}_A^e}^{\bar{P}_A}\right| < 1$. Thus, Eq. (8) can be written as:

$$FE_{y_{Ak}}^{\bar{P}_A} = \frac{\left|E_{y_{Ak}}^{\bar{P}_A}\right|}{1-\left|E_{\bar{m}_A^e}^{\bar{P}_A}\right|} \quad (10)$$

Through Eq. (14), "final impact of policy" can be calculated out, and further the proportions composed of "direct effect of policy" and "chain effect of social interactions" also can be distinguished.

## 4. VARIABLES AND DATA COLLECTION

### (1) Variables

The parking location choice behavior of scooter and bicycle users is assumed to the binary choice. The off-street parking (in parking lots) and the on-street parking (on sidewalks, arcades, and sides of road) are treated as two different alternatives. The explanatory variables in private utility include individual-specific variables ($\boldsymbol{X}_i$) and reference-group-specific variables ($\boldsymbol{Y}$). Although the expected average choice level of off-street parking of reference group (called "average choice level of group" for short) ($\bar{m}^e$) in social utility is also treated as an explanatory variable, its feature of endogeneity will be displayed in the modified elasticity analysis presented by this study. The adopted variables and their definitions are shown as Table 1.

### (2) Data collection

This study uses the method of stated preference to collect the data. The Taguchi Orthogonal Array (L32($2^1 \times 4^9$), for $\boldsymbol{Y}$ and $\bar{m}^e$) is adopted to design the combinations of scenarios in the stated preference survey, in order to solve the complexity caused by multiple attributes and their levels[38]. Subsequently, the visitors using scooter or bicycle to go to the city center of Tainan City are treated as the respondents. The sampling method is systematic sampling with a random start. Finally, the number of valid respondents is 192. The summary of questionnaire survey is shown in Table 3.

**Table 1.** The adopted explanatory variables and their definitions

| Variable | | Definition |
|---|---|---|
| Individual-specific variables ($\boldsymbol{X}_i$) | Parking duration ($x_{1i}$) | If the respondent parked for more than one hour, it is coded by 1. If the respondent parked for no more than one hour, it is coded by 0. |
| | Visit frequency ($x_{2i}$) | If the respondent visited the city center above 4 days per week, it is coded by 1. If the respondent visited the city center below 3 days, it is coded by 0. |
| | Modal use ($x_{3i}$) | If the respondent used scooters to visit, it is coded by 1. If the respondent used bicycles to visit, it is coded by 0. |
| | Moral consciousness ($x_{4i}$) | Using the factor analysis (the measured variable is shown in Table 2) to obtain factor scores. |
| | Risk attitude ($x_{5i}$) | Using the factor analysis (the measured variable is shown in Table 2) to obtain factor scores. |
| | Self-interest ($x_{6i}$) | Using the factor analysis (the measured variable is shown in Table 2) to obtain factor scores. |
| Reference-group-specific variables (policy variables) ($\boldsymbol{Y}$) | Distance ($y_1$) | It is assumed that there are four levels of distance from the parking lots to destinations without considering the limitation of parking capacity. They are 50m (meters), 150m, 250m, and 350m. |
| | Fixed cost ($y_2$) | It is assumed that there are two levels of fixed cost of using parking lots. They are NT$0 and NT$20 (per time within one day). |
| | Marginal cost ($y_3$) | It is assumed that there are three levels of marginal cost of using parking lots. They are NT$0, NT$10 (for more than 1 hour and less than 2 hours), and NT$20 (for more than 2 hours). |
| Average choice level of group ($\bar{m}^e$) | | It is assumed that there are four levels of the expected average choice level of off-street parking of reference group. They are 100%, 90%, 60%, and 30%, through transforming into choice proportion. |

**Table 2.** The measurement of psychological factors belonging to latent constructs

| **Latent constructs** | **Measured variable (Using five-point semantic scale to collective the responses that how much do the respondents care about the following items when they choose a parking location)** |
|---|---|
| Moral consciousness | 1. Destroying the streetscape<br>2. Impeding the commercial activities<br>3. Obstructing the passing of the disables<br>4. Obstructing the walking of pedestrians<br>5. Increasing traffic congestion and risk |
| Risk attitude | 1. Possibility of clamping down<br>2. Possibility of illegality<br>3. Possibility of the damage of scooter or bicycle |
| Self-interest | 1. Time consuming<br>2. Distance from the parking places to the destinations<br>3. Parking fee |

**Table 3.** The summary of questionnaire survey

| | | | |
|---|---|---|---|
| District: | | | central business district of Tainan City |
| Subject: | | | scooter and bicycle users |
| Date: | | | 2010/01/28 ~ 2010/04/14 |
| Time: | on daily days: | | 17:00~21:00 |
| | on weekend days: | | 15:00~21:00 |
| Survey method: | | | face-to-face interview |
| Sampling method: | | | systematic sampling with a random start |
| Number: | the number of people invited to join the interview: | | 1002 persons (100%) |
| | the number of people rejecting the interview: | | 722 persons (72.06%) |
| | the number of people accepting the interview: | non scooter and bicycle users: | 88 persons (8.78%) |
| | | **Scooter and bicycle users:** | **192 persons (19.16%)** |

## 5. ESTIMATION RESULTS

The all explanatory variables are specified the alternative specific variable for off-street parking for a better grasp of the influence of the explanatory variables. Consequently, the variables of which parameter signs are positive have a positive influence on the probability of choosing off-street parking, whereas the variable of which parameter signs are negative have a negative influence on the probability of choosing on-street parking. Besides, the number of scooter and bicycle users in the valid sample is 192, and it is multiplied by 4 since each respondent is provided four combinations of scenarios to make choice in the stated preference survey. Therefore, the sample size in the model totals 768.

This study builds four models and the estimation results are shown in Table 4. It is noted that the model 4 has better explanatory capacity and more parsimonious than other models. For this reason, the model 4 is treated as the final model underlying the follow-up policy evaluation. The influence of the variables is displayed in Table 4. Among these, the most important variable is average choice level of group whose parameter indicates the significantly positive influence of the variable on choosing off-street parking. This parameter used to measure the strength of social interaction implies that the scooter and bicycle users have a strong tendency to conform to the behavior of others when they park.

**Table 4 (1).** Estimation results of parking location choice behavior model

| — | Model 1 (not considering the individual heterogeneity) | | Model 2 (based on model 1, plus the travel characteristic) | |
|---|---|---|---|---|
| | Parameter | T-value | Parameter | T-value |
| Parking duration ($x_{1i}$) | — | — | -0.2050 | -1.17 |
| Visit frequency ($x_{2i}$) | — | — | -0.3296* | -1.90 |
| Modal use ($x_{3i}$) | — | — | -0.6354*** | -2.96 |
| Moral consciousness ($x_{4i}$) | — | — | — | — |
| Risk attitude ($x_{5i}$) | — | — | — | — |
| Self-interest ($x_{6i}$) | — | — | — | — |
| Distance ($y_1$) | -0.0055*** | -6.83 | -0.0056*** | -6.88 |
| Fixed cost ($y_2$) | -0.0921*** | -7.37 | -0.0941*** | -7.43 |
| Marginal cost ($y_3$) | -0.0379*** | -3.30 | -0.0391*** | -3.35 |
| Average choice level of group ($\bar{m}^e$) | 1.0824*** | 6.70 | 1.0983*** | 6.71 |
| Constant | 2.3834*** | 8.91 | 2.8478*** | 9.16 |
| Sample size | 768 | | 768 | |
| *LL(0)* | -532.337 | | -532.337 | |
| *LL(β)* | -422.469 | | -413.994 | |
| $\rho^2$ | 0.206 | | 0.222 | |
| $\bar{\rho}^2$ | 0.197 | | 0.207 | |

*p<0.1, **p<0.05, ***p<0.01

**Table 4 (2).** Estimation results of parking location choice behavior model

| — | Model 3 (based on model 2, plus the psychological factors) | | Model 4 (based on model 3, eliminating the insignificant) | |
|---|---|---|---|---|
| | Parameter | T-value | Parameter | T-value |
| Parking duration ($x_{1i}$) | -0.2489 | -1.40 | — | — |
| Visit frequency ($x_{2i}$) | -0.3133* | -1.77 | -0.3416** | -1.98 |
| Modal use ($x_{3i}$) | -0.4360* | -1.91 | -0.4036* | -1.84 |
| Moral consciousness ($x_{4i}$) | 0.3918* | 1.79 | 0.3681** | 2.36 |
| Risk attitude ($x_{5i}$) | 0.4270** | 2.18 | 0.4563** | 2.56 |
| Self-interest ($x_{6i}$) | -0.1224 | -0.46 | — | — |
| Distance ($y_1$) | -0.0057*** | -6.94 | -0.0056*** | -6.99 |
| Fixed cost ($y_2$) | -0.0963*** | -7.48 | -0.0951*** | -7.55 |
| Marginal cost ($y_3$) | -0.0399*** | -3.39 | -0.0398*** | -3.39 |
| Average choice level of group ($\bar{m}^e$) | 1.0552*** | 6.35 | 1.0510*** | 6.37 |
| Constant | 0.6001 | 0.75 | — | — |
| Sample size | 768 | | 768 | |
| *LL(0)* | -532.337 | | -532.337 | |
| *LL(β)* | -405.601 | | -406.783 | |
| $\rho^2$ | 0.238 | | 0.236 | |
| $\bar{\rho}^2$ | 0.217 | | 0.221 | |

*p<0.1, **p<0.05, ***p<0.01

## 6. ELASTICITY ANALYSIS FOR SOCIAL INTERACTIONS

This study proposed a modified elasticity analysis method considering the chain effect of social interactions. It is needed to adopt such method which is capable of dealing with social interaction effect because the phenomenon of social interactions has been confirmed in parking behavior according to the above estimation results.

Through Eq. (10), the "direct effect of policy" and the "chain effect of social interactions" can be distinguished and calculated out. The "direct effect of policy" is the scope that past elasticity analysis in discrete choice models deals with. The "chain effect of social interactions" is the past uncovered scope grasped here through the modified elasticity analysis method presented by this study. Therefore, this study can evaluate the final impact of policy, which equals to the summation of direct effect of policy and chain effect of social interactions, when manipulating the level of policy.

The result of policy evaluation is described as below (see Table 5). Firstly, based on a traditional effect evaluation method which is often employed in previous studies, the percentage change in the probability of individual choosing off-street parking would be 0.81% given that the distance (from the parking lot to the destination) decreases by 1%, whereas, under the same condition, the percentage change in the probability would be 3.38% according to the proposed method incorporating the chain effect of social interactions. Secondly, based on the traditional effect evaluation method, the percentage change in the probability of individual choosing off-street parking would be 1.76% given that the fixed cost (of using the parking lot each time) decreases by 1%, whereas, under the same condition, the percentage change in the probability would be 7.33% according to the proposed method. The analytical results reveal that the biases will exist in the evaluation of related policies if the social interaction effect is not considered in the analysis on the travel behavior which is influenced by social interactions.

**Table 5.** The final impact of policy and its composition

| Policy variable | Percentage change of the probability of choosing off-street parking as policy variable value decreases 1% | | |
|---|---|---|---|
| | ① Direct effect of policy ($\left\|E_{y_{Ak}}^{\bar{P}_A}\right\|$) | ② Chain effect of social interactions ($SE_{m_A}^{\bar{P}_A}$) | ③ Final effect of policy ($FE_{y_{Ak}}^{\bar{P}_A}=\left\|E_{y_{Ak}}^{\bar{P}_A}\right\|+SE_{m_A}^{\bar{P}_A}$) |
| Distance ($y_1$) | 0.81% | 2.57% | 3.38% |
| Fixed cost ($y_2$) | 1.76% | 5.57% | 7.33% |

**Traditional elasticity analysis method: ①**
**Modified elasticity analysis method: ③＝①＋②**

## 7. DISCUSSION

The presence of social interaction effect on scooter and bicycle parking behavior in Tainan city, Taiwan, is confirmed through the parking location choice behavior model incorporating social interactions in this study. Subsequently, this study grasps the process of social interactions and calculates the chain effect of social interactions that is incorporated into the policy evaluation. That is to say, in order to resolve the social dilemma of on-street scooter and bicycle parking, the authority need to be cautious with the spillover phenomenon when changing the level of parking policy or other significant factors influencing the parking behavior. The policy variables in this study are still limited, and therefore, the more related policy variables are taken into account in the subsequent research, the more abundant content of policy alternatives will be for practical work.

On the other side, in the dimension of theory, we need to notice that the behavior with the presence of social interactions may take on the possibility of multiple equilibria. For meeting this condition, the coefficient ( $J$ ) of the variable in social utility has to be significantly more than 1[8], while the parameter in this study cannot be rejected to equal 1. Thus, this study regard the scoter and bicycle parking behavior in the empirical case as taking on single equilibrium and develop the applicable modified method of elasticity analysis considering the chain effect of social interactions.

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