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Towards Smart Parking Management: Econometric Analysis and Modeling of Public-Parking-Choice Behavior in Three Cities of Binh Duong, Vietnam

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Abstract: In developing cities, newly emerging cities have started facing the problem of insufficient public parking facilities and ineffective regulations. To support the planning, design and management of the public parking system towards a smart and sustainable city vision, it is necessary to study deeply parking behaviors. This paper presents an empirical study on parking-choice behaviors of motorcycle users and car users in the emerging cities of developing countries through a case study of three cities in Binh Duong, Vietnam. To explore the behavioral mechanisms and influential factors, the multinomial logit parking choice models are developed using revealed preference and stated preference data. The users' overall satisfaction and perceived importance of parking lot design and service aspects are analyzed using order logistic regression. The revealed choices show no trade-off between parking fee and walking distance, as the users are not fully aware of parking locations and service features. However, the stated choice experiments prove a potential existence of the trade-off mechanism and differentiate significant factors in the decision of choices for the two user groups. The results bring insightful implications for the development of a smart public parking system.

Keywords: parking-choice behavior; revealed preferences; state preferences; smart parking management; newly emerging cities in developing countries

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1. Introduction

In developing countries, the demand for parking in high-urbanization areas has not been well addressed [1,2]. A drastic increase in personal vehicles, especially cars, has led to the consequences of rampant parking on streets and even on sidewalks. Understanding individuals' parking behavior is important for the development of parking infrastructure and services and balancing of parking supply and demand, thereby contributing to reductions in urban road congestion and illegal parking behavior. In addition, with a vision of developing smart cities, including smart mobility and smart parking, the research on parking demand and perceived services for public parking is important. The research results are useful for guiding the planning, design and management of public parking lots toward a smart parking system. Results-based solutions will contribute to reducing traffic congestion and air pollution, optimizing parking demand and supply [3], and improving user satisfaction [4]. This is especially important in the context of emerging urban areas of developing countries, where the urbanization has just started, as it is the right time to deliver strategic parking infrastructure and parking service management in the right way in order to avoid the problematic issues at later stages [5].

There are numerous studies on parking-choice behavior for the car-dependent cities [6–15], but there are few works on the mixed car and motorcycle cities [16–19], and most of these works were conducted in the large cities. While Truong and Ngoc [16] analyzed the impact of parking price and accessibility to public transport on transport mode choice, Vu [17] investigated the illegal parking behavior in Hanoi, Vietnam. Hoang et al. [18] analyzed the impacts of parking fee, walking distance, and waiting time as well as the effects of parking navigation methods with regard to motorcycle parkers in Chi Minh City, Vietnam. However, the impacts of other parking services, such as automatic payment or the pre-trip booking platform, on the users' parking lot choice have not been considered.

In the context of developing countries, including Vietnam, the behavior of car users and motorcycle users are argued to be different in aspects of daily travel choices [20–25]. To the best of the authors' knowledge, there is, however, no study that comparatively analyses the parking-choice behavior of these two groups to support the planning, design and management of parking infrastructure and services, especially for the context of emerging urban areas or the new cities with a vision toward smart cities. Understanding the parking behaviors in these cities is necessary to support the parking demand forecast, parking infrastructure planning and operational management for these cities. The objectives of this study are: (1) to investigate the behavioral mechanisms of public parking searching and choice making of car drivers and motorcycle riders in the context of the three cities as representative emerging urbans areas in developing countries; and (2) to analyze the parking users' perceptions and satisfaction with the quality of the public parking service in supporting the parking planning, design and management processes in the cities.

To achieve the objectives, the revealed preference (RP) and stated preference (SP) survey is adopted. The RP survey is used to explore the observed preferences of the parkers. Meanwhile, there are parking service factors that are not available in the RP context, such as the new policy instruments or new parking services. The complementary SP survey is used to explore the response of the parkers under various parking management policy settings, which include the distance from the parking lot to the final destination, parking cost/fee, and service factors (such as weatherproofing facilities, electronic cards, and security cameras), management factors such as fines for illegal parking and surveillance cameras. Statistical tools, such as multinomial logit models (MNL) and the ordered regression models, are deployed to model the behavior and quantify the impacts of the factors of interest.

The remaining part of the article includes six sections. The Section 2 presents an overview of related research. The Sections 3 and 4 ones summarize research methods and data collection. The Sections 5 and 6 sections present modeling results and discussions. The last section ends with conclusions and recommendations for future works.

2. Literature Review

There are numerous studies [1,14–19,26–32] on parking behavior with a variety of affecting factors. Parmar et al. [1] conducted an extensive review on the demand and characteristics of a parking system for the period from 1990 to 2018. Based on this work, the literature review in this section extends the search to the recent works addressing motorcycle parking issues and the parking decision-making mechanism in Table 1.

Among many factors, parking lots' characteristics such as parking cost, walking time/distance from the parking location to the final destination, time spent on searching for parking spots, and parking duration are at the top of frequently investigated factors (Figure 1).

Socio-economic characteristics of the users such as income and age are also popularly considered. Parking guidance and information (PGI) systems may include information technology applications, including software (apps) to help users to look up information on available parking spaces and parking fees [27], smart card systems that automatically calculate entry and exit times and the resulting parking fee, and camera-assisted systems [29]. To date, there have been few studies on the impact of PGI on the likelihood of choosing a type of parking equipped with these applications [27].

Table 1. Summary of parking behavior studies.

Reference	Authors	Method	Factors Considered	Objective
[6]	(Axhausen and Polak, 1991)	Rational decision making/Stated preference/Logit model	General in-vehicle time, parking search time, egress time, trip purpose	Car-parking-location-choice behavior
[33]	(Hunt and Teply, 1993)	Rational decision making/Stated preference/Nested logit model	Distance, waiting time, parking cost, parking surface condition, weather provision	Car-parking-location-choice behavior
[8]	(Golias J. et al., 2002)	Rational decision making/Stated preference/Binary logit models	Parking cost, search time for a parking space, parking duration, walking time from the parking space to the final destination	Car-parking-choice behavior
[19]	(Hu, 2007)	Rational decision making	Parking charge scheme	Motorcycle parking and mode choice behavior
[13]	(Ottomanelli et al., 2011)	Possibly theory	Parking price; the control and enforcement of illegal parking; distance between parking facility and final destination; congestion level of the parking facility, searching time	Car-parking-location-choice behavior
[12]	(Waraich and Axhausen, 2012)	Rational decision making/Large scale simulation in MATSim	Income, parking cost, walking distance, parking supply	Travel demand model
[23]	(John M. C. et al., 2012)	Irrational decision making/Game-based approach	Distribution of car park over time	Car parking strategy
[34]	(Kobus et al., 2013)	Rational decision making/Probit model	Parking duration, parking time, day of week, weather; parking price elasticity is small for short durations	On-street car parking behavior
[7]	(Ottosson et al., 2013)	Aggregate regression model	Parking rate, land use, parking price	Parking demand
[11]	(Guo et al., 2013)	Irrational decision making/Game-based approach/Dynamic sequential neo-additive capacity model	Psychological characteristics, occupancy, parking lot size	Car parking searching behavior
[35]	(Ibeas et al., 2014)	Rational decision making/Stated Preference/Mixed logit	Income, vehicle age, parking cost, access time to parking lot, access time from the parking lot to final destination	Car-parking-choice behavior
[17]	(Vu, 2017)	Rational decision making/Stated preference/Multinomial logit and Mixed logit models	Gender, age, income, walking duration, parking cost, illegal parking fine	Illegal parking behavior of car and motorcycle parkers
[9]	(Han et al., 2018)	Rational decision making/Multinomial logit model	Parking sharing policy, driver's age, the number of parking spaces, parking distance, seeking time	Car parking location choice

Table 1. *Cont.*

Reference	Authors	Method	Factors Considered	Objective
[36]	(Zong et al., 2019)	Structural equation model	Household income, number of household members, age, parking period, parking rate, parking duration, payment mode, walking, distance, trip purpose	Car parking period, parking location, and parking duration
[37]	(Khaliq et al., 2019)	Rational decision making/Mixed logit model	Parking costs, payment options, expected parking duration, speed limit, level of parking convenience, space availability and surrounding activities	Car parking period, parking location, and parking duration
[18]	(Hoang et al., 2019)	Rational decision making/Stated preference/Multinomial logit, Mixed logit model	Gender, age, driving experience, trip purpose, parking cost, walking distance, the capacity of the parking lot, queuing time.	Motorcycle parking
[1]	(Parmar et al., 2020)	Review	Ease of access, walk time, parking charges, parking guidance and information system, management, etc., at all stages of planning and policy formulation	Car parking related demand
[16]	(Thanh Truong and Ngoc, 2020)	Rational decision making/Stated preference/Multinomial logit model	Parking costs, walking distance and trip characteristics	Parking and location choice
[27]	(Ye et al., 2021)	Rational decision making/Stated preference/Multinomial logit model	Information technology applications, parking application information: available parking space, reserved and shared parking space, parking cost, distance to final destination, parked vehicle tracking	Parking application choice
[15]	(Ben Hassine et al., 2022)	Rational decision making/Reveal preference/Multinomial logit model	Age, residential land use, trip purpose, walking time, searching duration, parking cost	Car parking type choice
[14]	(Macea et al., 2023)	Rational decision making/Discrete choice model with latent variables	Travel time, cost, walking time to destination, availability of reserving and parking space, perception of risk for onstreet/off-street parking, pro-parking	Reserved-based parking behavior
[30]	(Rodríguez et al., 2023)	Rational decision making/stated preference/Mixed logit and Multinomial logit model	Cruising time, walking time to the destination, maximum allowed parking time, age of the vehicle, parking duration, annual permit for parking, trip purpose; parking cost	Parking-location-choice behavior
[31]	(Yan et al., 2023)	Structural Equation Model	Traffic conditions, parking facilities and environment	Illegal parking behavior
[32]	(Parmar et al., 2023)	Rational decision making/Hybrid discrete choice model with random coefficients	Mode/parking specific attitudes, built-environment factors and mode/parking-related attributes.	Mode and parking choice

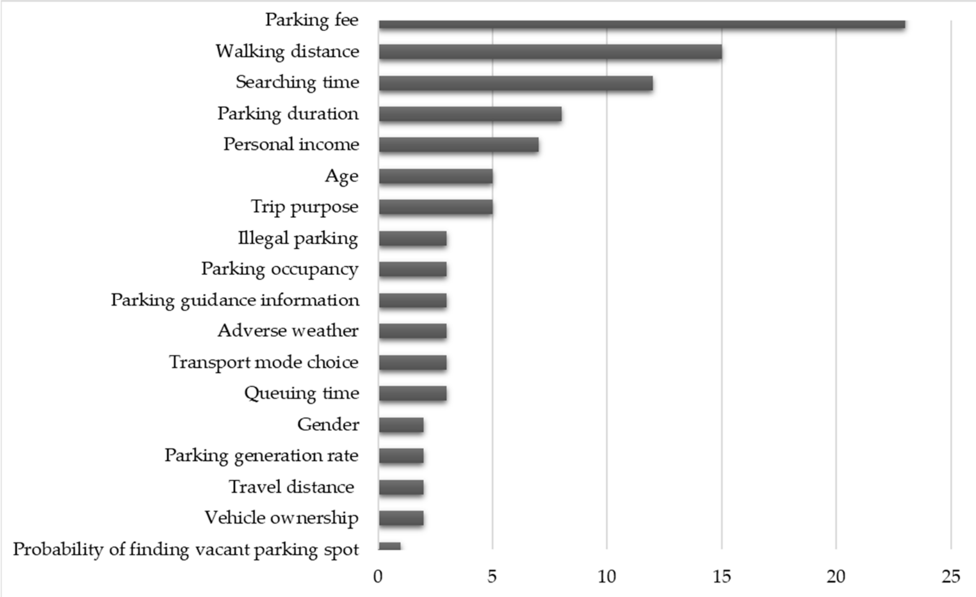

Figure 1. Factors of parking-choice behaviors in the literature.

To analyze parking-choice behavior, most researchers assumed a rational decision-making mechanism with which the users make decisions with full information of the parking alternatives. The most popular modeling approach is one using the econometric models which are based on the random utility maximization (RUM) theory [38]. For example, many researchers analyzed parking-location-choice behavior using the multinomial logit model (MNL) [9,15,16,18,27], with the assumption that choices are independent, or using the mixed logit model (ML) to consider heterogeneity in human behavior [10,18]. The nested logit model was also used by Hunt and colleagues [33] to build a model of parking-choice behavior. Guo et al. [11] compared two choice models built according to (1) a static game theoretical model, which assumes that drivers make decisions simultaneously with full knowledge of information about the characteristics of the parking lot; and (2) a dynamic neo-additive capacity model, which assumes that drivers do not have complete information about the parking lot and that decision-making depends on the psychological characteristics of uncertainty. The results showed that drivers' psychological characteristics affect their choice of parking location. An agent-based parking behavior model was applied by Waraich and Axhausen [12] to analyze individuals' choice of parking location using a case study in Zurich, Switzerland. The simulation process was based on a behavior model built on the utility maximization theory with consideration of factors such as parking fee level and capacity of the parking lot. Fang Zong et al. [36] adopted the structural equation modeling approach to analyze parking behavior of the users in Beijing, China. The results showed that parking price strongly affects parking duration.

The other authors argued that the parking decision is heuristic rather than rational. John M. C. et al. [23] adopted the simulation approach to study the parking search behavior. Results of the simulations draw on a simple parking search rule called "the fixed distance heuristic", which stated that the driver would park in the first vacant parking spot within some threshold range from the trip's final destination. Ottomanelli et al. [13] proposed a model for studying parking-choice behavior under uncertainty. The authors used the possibility theory to represent the decision-making of the drivers when they do not have complete information about traffic conditions in the area as well as information about parking lots, such as parking fees, distance from parking to destination, and penalties for illegal parking. The model results showed that these factors affect the driver's choice of parking location.

In the context of motorcycle-based countries, Thanh and Ngoc [16] built an MNL model to quantify the impacts of parking management policies on changes in mode choice and parking location choice in Hanoi, Vietnam. The variables included parking costs and trip characteristics. Tuan [17] analyzed factors affecting illegal parking behavior using hypothetical scenarios and logit models. It was found that the motorcycle parkers are more sensitive to the illegal parking fine level than the car parkers. Meanwhile, the parking behavior of motorcycle parkers was investigated by Hoang et al. [18] for the case study in Ho Chi Minh City, Vietnam. The findings were that parking fee, walking distance, the capacity of the parking lot, and queuing time significantly affect the motorcycle users' parking lot choice. Other considered factors were driving experience, age, gender, trip purpose and home location.

Up until this point, there seems to be missing research on parking-choice behavior in the emerging urban areas or small- and medium-sized cities of rapid urbanization in developing countries with a dominance of motorcycle use. There is limited knowledge about the parking location searching and decision-making mechanism of the parkers in the emerging cities with on-going infrastructure developments. In addition, the aspects of parking lot design and services, including parking guidance and information systems, have not been fully analyzed.

3. Methodology

To gain an understanding about parking behavior of the users in the emerging urban areas, this study takes the three cities of Binh Duong province as a case study. An RP–SP survey using a paper-based face-to-face interview method was conducted at existing parking facilities. The RP survey contains the questions inquiring the current parking experience of the parkers. This data source is able to reflect the actual market share. However, with the aims of exploring the potentials of new policy instruments such as a new parking charging scheme or new parking services, the SP technique is more relevant [39]. Therefore, the utilization of those two sources of data can provide better understanding about the parking behavior.

The first part of the questionnaire includes questions about their current trips and the knowledge level of the users on the availability of parking lots at their trips' destination and characteristics (price, parking guidance, distance, searching for vacant spot, etc.). There are also questions on how the users obtain the information about the parking lots at the trip destination. Data derived from the first part are used to develop the behavioral mechanisms of parking searching and choice making of drivers and riders in the study areas. The decision-making mechanisms of the local people are modeled using the MNL models, which are based on the RUM theory. MNL models assume that all alternatives in the choice set follow the independence of irrelevant alternatives (IIA) property [40]. The probability of choosing a parking lot i in the choice set of individual n, $Prob_{n,i}$ is expressed by Equation (1):

$$Prob_{ni} = \frac{\exp(V_{ni})}{\sum_{j=1,2,3} \exp(V_{nj})} \quad (1)$$

where: V_{ni} is the representative utility of alternative i for individual n, as an additive function of explanatory variable X_{ki}:

$$V_{ni} = \sum_{k=1}^{K} \beta_k X_{ki} \quad (2)$$

The second part of the questionnaire aims to collect data for analyzing the level of satisfaction and perceptions on the users' chosen parking lots. In total, 22 aspects related to parking lot building, parking services, accessibility and PGI are analyzed with the assumption that the perception of these aspects affects the overall satisfaction of individuals with the parking lot. This effect is quantified using the ordered logistic regression model which was first considered by Peter McCullagh in [41]. In this context, the dependent variable y is an ordered value indicating the overall satisfaction of an individual with 5 levels ranging from 1-Very satisfied to 5-Very dissatisfied. The probability of observing the satisfaction level i of individual n is given in Equation (3):

$$Prob(y_n = i) = Prob\left(\kappa_{i-1} < \beta X_j + u_j \leq \kappa_i\right) = \left(1 + e^{-\kappa_i + \beta X_j}\right)^{-1} - \left(1 + e^{-\kappa_{i-1} + \beta X_j}\right)^{-1} \quad (3)$$

where: κ_i is the cut-point at level i, κ_0 is defined as $-\propto$ and κ_5 as $+\propto$; u_j is assumed to follow the logistic distribution.

The third part presents stated choice experiments. Three parking options are considered in the questionnaire: (1) illegal on-street parking; (2) legal on-street parking; and (3) off-street parking. Each type of parking lot has common and unique characteristics. Based on the literature review, the attributes and design levels for each parking lot considered in this study are presented in Table 2. These factors are selected from among the ones that literally influence the choice of parking lot, including walking distance from the parking lot to the trip destination, parking fees, and illegal parking fine. In this experiment, the MNL models are also constructed to quantify the effects of the considered factors on the choice of parking lots under various stated scenarios. The sample of the questionnaire can be found in the Appendix A.

Table 2. Attributes' design levels.

Alternatives	Attributes	Car Park More than 2 h	Car Park Less than 2 h	Motorcycle Park More than 2 h	Motorcycle Park Less than 2 h
(1) Illegal on-street parking	Parking fee (VND) [1]				
	Walking distance (m)	<100 m; 100–200 m; 200–300 m; >300 m			
	Surveillance camera for detecting illegal parking	1: Available/0: Unavailable			
	Fine for Illegal parking (VND)	Zero 500,000 1,000,000 2,000,000		Zero 200,000 300,000 600,000	
(2) Legal on-street parking	Parking fee (VND)	Zero/2 h 15,000/2 h 30,000/2 h	Zero/turn 16,000/turn 24,000/turn 40.000/turn	Zero/2 h 4000/2 h 6000/2 h	Zero/turn 4000/turn 6000/turn 8000/turn
	Walking distance (m)	<100 m; 100–200 m; 200–300 m; >300 m			
	Apps for checking vacant spots, parking price	1: Available/0: Unavailable			
(3) Off-street parking	Parking fee (VND)	15,000/2 h 30,000/2 h	16,000/turn 24,000/turn 40,000/turn	4000/2 h 6000/2 h	4000/turn 6000/turn 8000/turn
	Walking distance (m)	<100 m; 100–200 m; 200–300 m; >300 m			
	Weatherproofing—Roof	1: Available/0: Unavailable			
	Electronic card for automatic check-in/check-out	1: Available/0: Unavailable			
	Security camera	1: Available/0: Unavailable			
	Apps for checking vacant spots, parking price	1: Available/0: Unavailable			

[1] USD~VND 23,000 in 2022.

The design levels in Table 2 should be chosen as close to the local people's experience [42]. Therefore, based on Vu, 2017 [17] and the Decree No. 100/2019/ND-CP of the Vietnamese Government, the value levels of attributes related to costs (parking fees and illegal parking fines) were chosen based on the authors' expectation of capturing the users' responses to policy changes. For illegal on-street parking, the lowest level is zero, indicating cases where there is a parking prohibited sign but no on-site patrol. This situation is often observed in many urban areas across the country.

Parking duration is also considered an important factor affecting parking lot choice behavior. This factor is accounted for by two design scenarios with short parking duration (parking less than 2 h) and long duration (parking more than 2 h). There are also separate scenarios for two groups, car drivers and motorcycle riders.

In summary, there are four groups to be investigated: (1) car parking for less than 2 h; (2) car parking for more than 2 h; (3) motorcycle parking for less than 2 h; and (4) motorcycle parking for more than 2 h (Table 2). For each group, 21 scenarios are generated from the orthogonal fractional factorial design. In one questionnaire, four scenarios are presented, including two scenarios of parking for less than 2 h and two scenarios of parking for more than 2 h.

The sample size designed for the regression model is determined based on the recommendation by Green [43]. The minimum sample size with medium effect size and 22 predictors is N = 104 + 22 = 126. Regarding sample size for estimating the MNL model for SP data, Bliemer and Rose [44] suggested a minimum value of 337 for the four-level attribute design with narrow-level range.

4. Data Collection

4.1. The Study Area

This research considers the case study of the three cities, namely Thu Dau Mot, Thuan An and Di An in Binh Duong province, Vietnam, as emerging urban areas. The three cities have formed a rapidly growing urban region of Binh Duong province, attracting development investments and population migrations. In recent decades, Binh Duong has become a rapid industrialization and dynamic economic region of the country with the highest foreign direct-investment attraction [45]. Having built upon industrialization, administrative reform and high-quality human resources [45–47], Binh Duong has been transitioning to a smart city region as a key to avoiding the middle-income trap. Smart mobility is apparently one of the core components of the smart city, and smart parking is essentially part of the smart mobility [48].

The total area of the three cities Thu Dau Mot, Thuan An and Di An is 262.67 km^2. The average population density is 5401 inhabitants/km^2. Di An has the highest density among the three, with more than 7700 inhabitants/km^2, following by Thuan An with nearly 7400 inhabitants/km^2. According to the statistics office, the number of registered vehicles in the study areas were more than 942,000 motorcycles and 98,530 cars in 2021. As a rough estimate for this study, the parking demand in the city central areas was about 1,433,570 motorcycles and 67,866 cars per day in 2022. The existing public parking facilities in the central areas, however, serve just less than 6% of the demand (Table 3).

Table 3. Off-street parking capacity in three cities.

	Car		Two-Wheeled Vehicles (Motorcycle, Bicycle, E-Bike...)	
	Number of Parking Spots	**Area (m^2)**	**Number of Parking Spots**	**Area (m^2)**
Thu Dau Mot	646	17,620	2670	16,165
Di An	810	2500	1000	3000
Thuan An	850	46,650	4150	19,000

4.2. Interview Survey

The survey was conducted in September 2022, using a paper-based face-to-face, on-street interview. A stratified sampling technique was deployed for the sample design, with the population divided by age, gender and residential area. As motorcycle use is very popular in the studied cities, the motorcycle users were randomly invited. Since the car users are difficult to approach, a convenience sampling technique (i.e., respondents are not randomly selected) was adopted for this group. With 600 questionnaires distributed, 200 per city, the number of valid questionnaires returned was 378, about 126 per city, corresponding to 1512 choice scenarios. Of the 378 questionnaires, the number of car parkers was 126 and the number of motorcycle parkers was 252.

4.3. Descriptive Analysis

Table 4 presents the descriptive statistics of the sample with 378 respondents. On socio-economic characteristics, the respondent average age is 37.8, and the ratio of males is 47.9%, slightly less than that for females in the sample. The average income of the car parkers is 21.238 million VND/month, which is nearly double the average income of motorcycle parkers. The average distance of reported trips and parking duration are nearly 12 km and 2.6 h, respectively. These values are similar for car parkers and motorcycle parkers.

Table 4. Descriptive statistics of all sample.

Attribute (Sample Size = 378)		Frequency	Percentage
Socio-economic	Male	181	47.9%
	Female	197	52.1%
	Average age	37.9	
	Personal income of motorcycle parkers (mil. VND)	11.275 (5.466)	
	Personal income of car parkers (mil. VND)	21.238 (7.632)	
Trip distance (km)		11.67 (5.2)	
Frequency of visiting the trip destination	First time	51	13.5%
	Sometimes	153	40.5%
	Quite frequent	174	46.0%
Trip purpose	Residency	122	32.3%
	Working	90	23.8%
	Education	26	6.9%
	Shopping	65	17.2%
	Entertainment/Eating out	54	14.3%
	Transferring	6	1.6%
	Others	15	4.0%
Parking fee	Motorcycle (thousand VND/turn)	3.192 (1.860)	
	Car (thousand VND/turn)	17.980 (10.251)	
Parking duration (hour)		2.6 (0.8)	
Parking facility	Free on-street	224	59.3%
	Paid off-street—Surface parking	21	5.5%
	Paid off-street—Roof parking and manual payment	107	28.2%
	Paid off-street—Roof parking and automatic payment	26	6.9%
Pre-trip search for the current parking lot information	Yes, I searched via the internet	21	5.6%
	Yes, I asked my relatives/friends	24	6.3%
	No, I knew this parking lot	248	65.6%
	No, I followed the parking signs	8	2.1%
	No, I cruised around searching for this parking lot	34	9.0%
	No, I asked people nearby	43	11.4%
Aware of the other parking lot	Yes	114	30.2%
	No	264	69.8%

For the trip purpose, the highest share is residency, with more than 32%, followed by the working, shopping and entertainment/eating-out trip with nearly 24%, 17% and 14%, respectively.

For the question asking if the parker searched for the parking lot information before or during the trip, nearly 88% of the respondents did not search. About 70% of them knew the parking lot themselves. About 85% of the respondents visited the destination more than one time. When being asked if they know another or alternative parking lot nearby, 264 respondents (70%) said that they do not know about the other one.

With 114 individuals (30%) reporting their parking lot alternatives, the comparison between the parking lot used and the alternative one is presented in Table 5. The users tend to park at the location near the trip destination, even if the parking fee is higher.

Table 5. Comparison between chosen parking lot and alternative parking lot.

Attributes (Sample Size = 114)		Chosen Parking Lot	Alternative Parking Lot
Parking cost (thousand VND)	Motorcycle	1.7 (2.1)	0.72 (2.4)
	Car	6.3 (10.2)	1.97 (5.0)
Searching duration (minutes)	Motorcycle	2.4 (1.2)	3.9 (1.6)
	Car	2.6 (1.3)	4.3 (1.5)
Walking distance to trip destination (m)	Motorcycle	289.3 (164.4)	479.6 (264.8)
	Car	279.1 (137.2)	477.9 (272.4)
Walking duration to trip destination (minutes)	Motorcycle	3.6 (2.4)	8.8 (2.8)
	Car	3.5 (2.5)	9.3 (3.1)
Parking facility	Free on-street parking lot	59.26%	85.96%
	Paid on-street parking lot	-	2.63%
	Surface parking lot	5.56%	3.51%
	Roof parking lot—manual payment	28.31%	7.89%
	Roof parking lot—automatic payment	6.88%	-
Parking guidance	Parking signs	19.30%	30.63%
	Parking attendant	28.07%	14.41%
	No guidance	52.63%	54.95%

Table 6 presents the average evaluation of the respondents of various aspects of parking lot design and services. The overall satisfaction was scored using a 5-point Likert scale ranging from 1—Very satisfied to 5—Very dissatisfied. Each design or service item was evaluated using a 5-point Likert scale ranging from 1—Very good to 5—Very bad. In general, the respondents were quite satisfied with their current parking lots (mean = 1.82). They also perceived the parking design as being of good quality (mean ranged between 1.23 and 1.98), except for the parking guidance facilities (mean = 2.95) and the availability of booking application (mean = 4.27).

Table 6. User satisfaction with and perceptions of the quality of parking lots used.

Aspect	Nr. of Observations	Mean	Std.	Min	Max
Overall satisfaction	376	1.82	0.72	1	3
Clear visual conditions inside the parking lot	378	1.47	0.61	1	3
Design of aisles inside the parking lot	378	1.64	0.88	1	4
Convenient maneuver inside the parking lot	378	1.52	0.64	1	3
Design of driveway/accessibility to the parking spot inside the parking lot	378	1.51	0.63	1	3
Building structure of the parking lot	378	1.55	0.64	1	3
Building architectural design of the parking lot	378	1.72	0.72	1	4
Floor height of the parking lot	377	1.03	0.18	1	2
Size of parking spot	378	1.72	0.64	1	3
Parking attendant attitude	325	1.79	0.68	1	4
Availability of parking guidance (digital boards, signs)	378	2.95	1.22	1	5
Availability of parking spots	378	1.30	0.49	1	3
Security cameras inside the parking lot	378	1.98	0.97	1	4
Safety equipment in the parking lot	326	1.29	0.60	1	4
Parking fee	378	1.42	0.49	1	2
Availability of electronic payment system	326	1.60	0.64	1	3

Table 6. *Cont.*

Aspect	Nr. of Observations	Mean	Std.	Min	Max
Availability of parking application (pre-trip information, booking, payment)	378	4.27	1.26	2	5
Walking distance to trip destination	378	1.30	0.49	1	3
Parking rules and facilities to ensure vehicles are parked in an orderly way (marking. . .)	378	1.32	0.51	1	3
Weatherproofing equipment	378	1.23	0.45	1	3
Floor cleanliness	378	1.23	0.45	1	3
Design of Entrance and Exit	378	1.22	0.44	1	3
Ventilation system inside the parking lot	378	1.25	0.46	1	3

5. Modeling Results

5.1. Observed Parking Choice Behaviour

The RP parking lot choice behavior was modeled using the MNL model. The parkers are assumed to consider a set of choices of three parking lot alternatives:

(1) Free on-street parking lot;
(2) Off-street parking lot;
(3) Other parking lot that individuals are aware of. Individuals who reported that they do not know another parking lot would be given the first two alternatives in the choice set.

Explanatory variables considered include: (1) generic variables such as parking fee, searching duration for vacant spots and the walking distance to the trip destination; and (2) trip-specific variables such as trip purpose, trip duration and parking duration. During the model development process, the socio-economic variables were also considered, but were insignificant. Therefore, these variables were left out in the final analysis.

The Biogeme software version 3.2.6 [49] was used to estimate the model, with the results presented in Table 7. The rho-squared bar value of 0.416 suggests a good fit of the model to the data. Estimated parameters of the generic variables suggest that individuals only care about the walking distance and the searching duration for vacant spots at the parking lot. The parameter associated with residency parking shows that the probability of on-street parking for this trip purpose is higher than for the other trips. This reflects the situation where there is a lack of public parking lots in the residential neighborhood and residency parking management in the study area.

The parking fee parameter, however, is statistically significant and positive, which is contradictory to the economic theory. There is no trade-off between the walking distance (or the searching duration) and the parking fee. The positive sign for the parking fee parameter could be explained by the fact that the current parking price is relatively low in the study area. Furthermore, this finding could be partially explained by the phenomenon “the fixed distance heuristic” of John M. C. et al. [50], which stated that the driver would park in the first vacant parking lot within a threshold range from the trip destination. The descriptive statistics in Tables 4 and 5 also indicated that the local people seem to be relying on their own experience about their cities to make parking choice decisions. This is actually in line with Khattak and Polak [51], who state that “individuals who believe they “know best” are less inclined to depend on parking information”. In the situation where there is a lack of well-planned parking facilities and information, the parkers might not behave in a rational manner, but might follow a heuristic rule.

The RP model results imply that the current practice of smart parking management in the study area are insufficient. To help realize the smart parking management, not only should additional parking lots be strategically provided, but also the parkers’ sensitivity to parking lot design and service information should be further investigated and practiced upon.

Table 7. Estimated revealed parking-choice-preference model.

Variable	Alternative	Value
Alternative specific constants	On-street parking	0 (constraint)
	Off-street parking	−0.955 (−1.34)
	Other parking lot	−16.6 (−4.68) ***
Parking fee	All alternatives	0.722 (3.18) **
Duration of searching for parking spot	All alternatives	−5.06 (−2.42) *
Distance to trip destination	All alternatives	−0.027 (−2.52) *
Dummy: Parking guidance (1: Available, 0: otherwise)	Off-street parking	0.565 (1.84)
Trip duration	On-street parking	0.0173 (1.84) .
Dummy: Entertainment trip	Off-street parking	0.168 (0.466)
Dummy: Residential location	On-street parking	0.741 (2.36) *
Parking duration	Off-street parking	0.0406 (0.203)
Sample size		323
Rho-square bar		0.416
Akaike Information Criterion		289.4022
Bayesian Information Criterion		327.1787

Significance codes: "***": $p < 0.001$; "**": $p < 0.01$; '*': $p < 0.05$; '.': $p < 0.1$. Robust *t*-test in parenthesis.

5.2. User Perceived Importance of Parking Lot Design and Service Factors

This section presents the analysis of the parkers' preferences for parking lot design and services, in order to find out what aspects are considered important from the users' perspective. Ordered logistic regression models were constructed for the two groups, motorcycle parkers and car parkers. The dependent variable is the overall satisfaction of the parker with the parking lot used. The dependent variables are 22 design and service aspects. The models were estimated using Stata 14 [52]. Table 8 presents the estimation results. The pseudo R2 values of 0.366 for the motorcycle parker group and 0.513 for the car parker group indicate that the included independent variables contribute to the explanation of the dependent variable.

The results reveal similarities and dissimilarities in the parkers' perceptions of the design and service aspects of their chosen parking lots. First, for both groups, the following aspects, if improved, may not contribute to their higher satisfaction: (i) clear visual conditions inside the parking lot; (ii) design of aisles inside the parking lot; (iii) design of driveway/accessibility to the parking spot; (iv) building structure of the parking lot; (v) building architectural design of the parking lot; (vi) floor height of the parking lot; (vii) size of parking spot; and (vii) security cameras inside the parking lot. Most of these aspects relate to the construction of the parking lots.

Second, for both groups, the following aspects, if improved, would contribute to their higher satisfaction: (i) safety equipment in the parking lot; (ii) parking fee; (iii) availability of electronic payment system; (iv) availability of parking application; and (v) ventilation system inside the parking lot. However, the car parkers perceive a greater importance of those factors, meaning that if these aspects are improved, they would be much happier than their counterparts—the motorcycle parkers.

Third, the two groups have dissimilar perceptions of the following aspects, due to the differences in the occupied parking space, parking maneuvering, and vehicle value between the two. While motorcycle parkers perceive convenient maneuver inside the parking lot, parking attendant attitude and availability of parking guidance (digital boards, signs) important for their satisfaction, car parkers do not. While car users value factors like the availability of parking spots, walking distance to trip destination, parking rules and facilities to ensure the vehicles are orderly, weatherproofing equipment, floor cleanliness, and design of entrance and exit, motorcycle parkers do not do so.

Table 8. Estimated ordered logistic regression models of user satisfaction and contributing factors.

Aspects of Parking Lot Design and Services	Motorcycle Parkers	Car Parkers
Clear visual conditions inside the parking lot	0.31 (1.02)	0.09 (0.17)
Design of aisles inside the parking lot	0.08 (0.40)	0.24 (0.57)
Convenient maneuver inside the parking lot	0.64 (2.14) *	0.24 (0.44)
Design of driveway/accessibility to the parking spot	0.03 (0.12)	0.12 (0.21)
Building structure of the parking lot	0.30 (1.18)	0.59 (1.18)
Building architectural design of the parking lot	0.29 (1.16)	0.24 (0.42)
Floor height of the parking lot	0.80 (0.61)	2.57 (1.21)
Size of parking spot	0.18 (0.55)	0.19 (0.35)
Parking attendant attitude	0.76 (2.56) *	0.27 (0.49)
Availability of parking guidance (digital boards, signs)	0.52 (2.73) **	0.14 (0.46)
Availability of parking spots	0.64 (1.27)	1.60 (1.72)
Security cameras inside the parking lot	0.00 (0.00)	0.33 (1.02)
Safety equipment in the parking lot	0.97 (2.20) *	3.93 (3.91) ***
Parking fee	1.77 (3.56) ***	4.91 (4.61) ***
Availability of electronic payment system	0.87 (1.65)	3.38 (2.33) *
Availability of parking application (pre-trip information, booking, payment)	0.44 (2.71) **	0.98 (2.86) **
Walking distance to trip destination	0.10 (0.15)	3.47 (2.33) *
Parking rules and facilities to ensure vehicles are parked in an orderly way (marking. . .)	1.47 (0.98)	6.87 (2.54) *
Weatherproofing equipment	1.32 (0.67)	4.03 (1.96) *
Floor cleanliness	0.17 (0.11)	6.81 (2.37) *
Design of Entrance and Exit	1.07 (0.54)	4.31 (1.73)
Ventilation system inside the parking lot	2.09 (3.20) **	5.11 (3.32) ***
/cut1	0.66 (std. 1.75)	4.46 (std. 2.48)
/cut2	3.67 (std. 1.78)	7.82 (std. 2.60)
Number of observations	215	107
Likelihood Ratio—chi2(22)	166.74	114.65
Prob > chi2	0	0
Pseudo R2	0.366	0.513

Significance codes: "***": $p < 0.001$; "**": $p < 0.01$; '*': $p < 0.05$; (z-value in parenthesis).

5.3. Stated Preference for Parking Choice Behaviour

This section further explores potential changes in the parker behavior under several settings of selected design and service aspects of public parking lots. In this experiment, the parkers receive information on parking design and service features through being exposed themselves to various choice scenarios. In practice, parking information will be disseminated to the users via channels like websites, apps, radio, podcasts, flyers, etc. To measure potential impacts of new schemes relating to parking fee, walking distance, parking application, illegal parking reinforcement, etc., four MNL models were constructed for car and motorcycle parkers with long and short parking duration. The estimation was also performed by using the Biogeme 3.2.6 software, with the results presented in Table 9. During the development process, the socio-economic and trip characteristic variables were considered in the model specifications. These variables were, however, insignificant and thus left out in the final analysis. The rho-square bar values ranging from 0.324 to 0.409 suggest a good fit for the data.

The estimated parameters of parking fees, illegal parking fines, and parking distance have negative values, as expected, and are statistically significant at a level above 99%. This is a reasonable result, indicating that people are sensitive to parking fees, illegal parking fines, and walking distance from the parking lot to their trip destination. These findings are consistent with the results of previous studies [15–18,26]. Different from the observed behavior in which the parkers make a decision with limited information about the parking options, under fully provided information, the trade-off between the walking distance and parking fee is confirmed.

Table 9. Estimated stated preference for parking choice models.

Variable	Alternative	Motorcycle Park		Car Park	
		More than 2 h	**Less than 2 h**	**More than 2 h**	**Less than 2 h**
Alternative specific constants	Illegal on-street parking (constraint)	0.000	0.000	0.000	0.000
	On-street parking	1.14 (3.33) ***	0.64 (2.01) *	−0.369 (−0.809)	0.0572 (0.133)
	Off-street parking	1.4 (3.37) ***	0.957 (2.54) *	−0.208 (−0.394)	0.768 (1.5)
Parking fee	All alternatives	−0.226 (−6.01) ***	−0.261 (−7.34) ***	−0.0442 (−4.2) ***	−0.0721 (−5.96) ***
Distance to trip destination	All alternatives	−0.147 (−3.37) ***	−0.173 (−4.31) ***	−0.205 (−3.43) ***	−0.231 (−3.89) ***
Illegal parking fine	Illegal on-street parking	−5.97 (−50.7) ***	−5.81 (−52.9) ***	−2.63 (−38.4) ***	−2.75 (−37.4) ***
Dummy: Surveillance camera (1: Available, 0 otherwise)	Illegal on-street parking	0.403 (0.939)	−0.489 (−1.17)	−0.336 (−0.559)	−0.522 (−0.88)
Dummy: Parking App (1: Available, 0 otherwise)	On-street parking and off-street parking	−0.072 (−0.544)	0.179 (1.23)	0.484 (2.54) *	0.0415 (0.201)
Dummy: Security camera (1: Available, 0 otherwise)	Off-street parking	0.303 (1.57)	0.519 (2.57) *	0.389 (1.41)	0.0792 (0.251)
Dummy: Roof (1: Available, 0 otherwise)	Off-street parking	0.0776 (0.397)	0.35 (1.76) .	0.236 (0.835)	0.52 (1.6)
Dummy: E-card (1: Available, 0 otherwise)	Off-street parking	0.436 (2.25) *	0.131 (0.651)	0.271 (0.961)	0.523 (1.66)
Sample size		504	504	252	252
Rho-square bar		0.324	0.347	0.334	0.409
Akaike Information Criterion		748.4143	723.1217	368.577	327.066
Bayesian Information Criterion		790.6401	765.3474	403.871	362.360

Significance codes: "***": $p < 0.001$; '*': $p < 0.05$; '.': $p < 0.1$. (Robust *t*-test in parenthesis).

The parkers are more sensitive to the parking fee for the short duration than for the long duration. This result is in line with the finding in a case study for the city of Almere, a young city in the Netherlands [34], which is that if the parking price for short duration slightly decreases, the parking demand strongly increases. Given the same increase in parking fee, the likelihood of parking for less than 2 h decreases more than in the case of parking for more than 2 h. Comparatively, the motorcycle parkers are more sensitive to the parking fee and illegal parking fines, but less sensitive to walking distance than the car parkers. Tuan [17] also found that the motorcycle parkers are more sensitive to the illegal parking fine than car parkers. These results are understandable because the car parkers generally have a higher income than motorcycle users.

The effect of walking distance on parking for less than 2 h is higher than for parking more than 2 h in both groups. This result means that when parking for a short duration the parkers tend to choose closer parking lots than in the case of parking for a long duration.

The estimated parameter of the presence of surveillance cameras monitoring illegal parking behavior is not statistically significant. This finding suggests that the surveillance camera system would not help reduce illegal on-street parking unless the fines are enforcedly collected upon the detection of illegal parking behavior.

For the availability of a parking application, the estimated parameter is statistically significant at 95% only for the model of car parking for longer than 2 h. The positive sign of this coefficient means that the likelihood of choosing the paid parking lot is higher if the application for checking information is available. The same parameter for the other groups is not statistically significant, and can be partly explained by the fact that these individuals may not be interested in using the application.

The availability of electronic cards helps increase the likelihood of choosing off-street parking lots for the motorcycle parkers parking for a shorter period than 2 h. For the motorcycle parking for longer than 2 h, the security cameras equipped at off-street parking lots also help increase the likelihood of choosing this type of parking facility.

Based on these results, implications for parking management and policy are discussed in the next section.

6. Managerial and Policy Implications

6.1. Parking Lot Quality and Services

To improve the experience and satisfaction of parking users, priority measures should be taken to enhance the aspects perceived important by the users. For both groups, the priorities are safety equipment, parking fee, availability of electronic payment system, availability of parking application, and ventilation system. Among these, the availability of parking application (pre-trip information, booking, payment) must be urgently improved, as the users perceive it to be poor. The result of parkers' overall satisfaction and perceptions also suggest a differentiation of design regulations for car and motorcycle parking lots. On the one hand, for motorcycle parking lots, the parking guidance information is among the important service aspects that contribute to user satisfaction. In addition, design of traffic lanes, size, layout and separation between parking spots should be considered to ensure the convenience of parking maneuvers and to contribute to the parkers' satisfaction. Professional training should be provided to improve attendant behaviour and attitude toward motorcycle parkers. On the other hand, for car parking lots, the capacity and design of parking entrances are aspects to be improved. The results of the SP analysis confirmed that parking application and electronic payment system, if available, are the most important factors that contribute to choosing off-street parking lots. As such, parking operators should supplement or upgrade information services. This would help to reduce the time spent searching for vacant parking spots around the destination, making the off-street parking lot more accessible to the parkers.

6.2. Provision of Parking Information via PGI and Intelligent Parking Guidance

The analysis of observed parking-location-choice behavior reveals that the residents often go directly to the parking facility at the destination without searching for parking information prior to or during the trip. There is no trade-off between parking fee and the walking distance in the parkers' decision-making processes. This habitual behavior would dampen the expected outcome of parking policies, which aim to increase off-street public parking just through construction and pricing measures. In the context of the study area, not only should the parking facility be improved, but also the provision of parking information for the parkers is worth attention.

Studies have shown the impact of information provision on parking-choice behavior [51]. For a smart parking system and smart city development, it is important to provide a centralized parking information system accessible to all parkers. A PGI (parking guidance information) service is important for parkers who park for longer than 2 h. Information provision via smartphones is considered the most effective way, as the smartphone is widely used. Well-designed marketing and publicity campaigns may help accelerate the penetration of smartphone-based parking information applications [27]. It is also important to develop a data center on parking demand and supply. Parking demand data can be generated with a comprehensive design of smart parking architecture with the use of multiple sensors, electric devices and a wireless network for the connectivity between the infrastructure and the users [53–55]. To support data integration, the authorities should provide guidance on the provision of parking information.

6.3. Illegal Parking Management

To eliminate the illegal parking issue, the fine-level and patrol systems are important. As there would still be a significant proportion of parkers (about 10%) who would still illegally park their vehicles on streets, especially for short durations (less than 2 h), the authorities should provide information signs and post the fine levels for illegal parking in parking-prohibited areas. The installation of surveillance cameras to monitor illegal parking behavior works only if the fines are strictly and successfully collected, because it helps to strongly deter the behavior. Surveillance cameras are considered cost-effective for illegal parking management [56]. Artificial intelligence cameras can help to automatically detect illegal parking behaviors and generate the information about the vehicles and the illegal parkers for post-violation enforcement and penalty collection.

6.4. Comprehensive Planning of Parking Locations and Charging Scheme

Firstly, since residents mainly utilize on-street parking, the authorities should take into account this kind of parking demand. Studies have shown that increasing off-street parking lots in residential areas might not contribute to the decrease in on-street parking [11]. As such, residential parking management programs, such as permission rules, a pricing scheme [57] or a combination of vehicle ownership [58] are worth consideration.

Secondly, the SP parking choice models indicated that the parkers are sensitive to both parking fee and walking distance. In addition, parking duration also affects parking-choice behavior. In the case of short durations, the parkers are more likely to choose parking lots closer to the destination at higher fees than in the case of long durations. The planning of public parking locations needs to find a balance between the location and the fee scheme. The fees at on-street parking lots should be set higher than the ones at off-street parking lots in order to promote the demand for off-street parking facilities. Furthermore, given the same increase in parking fee, the likelihood of choosing parking may decrease faster in the case of parking for shorter period than 2 h than in the case of parking for longer than 2 h. As such, setting rather low fees for short durations and much higher fees for long durations could enhance the demand for off-street parking lots relative to on-street parking lots.

Thirdly, motorcycle parkers are more sensitive to parking fees and illegal parking fines, but less sensitive to walking distance than car parkers. Therefore, the design of a parking charging scheme should differentiate the two groups. For car parkers, higher parking fees should be set in the city center. However, for motorcycle parkers, illegal parking enforcement and low-fee schemes should be set in combination with Park and Ride facilities for better accessibility to public transport [16,19].

7. Conclusions

This paper has presented an analysis of parking behavior of both car and motorcycle parkers in emerging urban areas of developing countries, with the case study of the three cities in Binh Duong province, Vietnam. The key results are summarized as follows.

First, the analysis of revealed parking behavior found that parkers in the study area do not have a habit of searching for parking information before or during the trips. With limited information, the choice of parking location is not dependent on the parking fee, but on the distance to the final destination of the trip. The result also indicated the lack of parking inventory and smart parking management in the study area. Second, to support the parking management, the parker perceptions of parking design and services were investigated. The results revealed that the availability of parking guidance facilities, electronic payment method, and parking application are among aspects that contribute to the parkers' satisfaction. In addition to parking fee, walking distance and illegal parking, some of the aspects were further considered in the stated parking choice experiment to explore behavioral changes under various settings of parking management measures. With the full information about parking options at the destination, the parkers showed the trade-off between parking cost and the walking distance. The availability of parking applications and electronic cards was found to contribute to the higher probability of choosing off-street parking lots. Based on such key findings, managerial and policy implications were discussed with regard to parking lot quality and services, provision of parking information via PGI and intelligent parking guidance, illegal parking management, comprehensive planning of parking locations, and a charging scheme.

To the authors' knowledge, this is the first study of the emerging urban areas of developing countries. In practice, the study provides insights into the local people's parking choice behavior and into the strategic planning, quality design and smart management of urban parking systems, particularly public parking systems. The results contribute to the literature on parking choice behavior with empirical evidence from emerging cities in developing countries. The methodology, consisting of examining the observed behavior using an RP survey, exploring parkers' preferences for parking design and service, and investigating behavior changes using an SP technique, can be adopted for other cities that share the vision of smart parking management with the study area.

The study has identified some limitations. First, the local habits of searching for and choosing parking lots are very interesting, but still need to be explored more deeply through a comprehensive research design. Second, to design smart parking management as a travel demand management tool, the hypothetical scenarios for parking location choice should consider public transport alternatives. Further studies should include Park and Ride and PGI in the scenarios. The effects of such variables on the parker behavior will be essential for designing smart parking in cities.

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Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Ethics Committee of the Vietnamese-German University (protocol code No:01/VGU-QLNCKH 19/9/2023).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data used for this study are available at the Binh Duong Province's Department of Science and Technology. Restrictions apply to the availability of these data, which were used under the license for this study. Data are available from the authors with the permission of the Department of Science and Technology.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A List of Questions

I—General information

Q1. Gender: 1. Male 2. Female

Q2. Age:

Q3. Monthly income: (million VND/month)

Q4. Parked vehicle: 1. Motorcycle 2. Car

Q5. Trip purpose:

1. Residency 2. Working 3. Education 4. Shopping 5. Entertainment/Eating out 6. Transferring 7. Others

Q6. Trip distance: (km)

Q7. Frequency of visiting the trip destination: 1. First time 2. Sometimes 3. Quite frequent

II—Parking searching and parking lot characteristics

Q8. Type of parking facility

1. Free on-street parking
2. Paid on-street parking
3. Illegal on-street parking

4. Paid off-street, surface parking
5. Paid off-street, roof parking, manual payment
6. Paid off-street, roof parking, automatic payment

Q9. Parking duration

1. Less than an hour 2. About 1~2 h 3. About 3–4 h 4. About 5–8 h 5. More than 8 h

Q10. Parking cost: (VND)

Q11. Parking-spot search duration: (minutes)

Q12. Availability of parking guidance in the parking lot?

1. Digital boards 2. Sign boards 3. Parking attendants 4. Unavailable

Q13. Distance to the trip destination: (m) walking duration: (minutes)

Q14. Did you search for parking information at the destination (location, cost) before and during the trip?

1. Yes 2. No

Q15. If your anwser in Q14 is yes, which source of information did you search?

1. I searched via the internet 2. I used a parking application 3. I asked my relatives/friends 4. I called the person in charge at the destination

Q16. If your anwser in *Q14* is "No", how do you find this parking location?

1. I knew this parking lot 2. I followed the parking signs 3. I cruised around searching for this parking lot 4. I asked people nearby

Q17. Do you know another nearby parking location? 1. Yes, I do 2. No, I don't

If your anwser is "Yes", please describe the parking location with the following information:

Q18. Type of parking facility:

1. Free on-street parking
2. Paid on-street parking
3. Illegal on-street parking
4. Paid off-street, surface parking
5. Paid off-street, roof parking, manual payment
6. Paid off-street, roof parking, automatic payment

Q19. Parking cost: (VND)

Q20. Parking-spot search duration: (minutes)

Q21. If you choose to park your vehicle at this alternative location, which parking guidance would you receive?

1. Digital boards 2. Sign boards 3. Parking attendants 4. Unavailable

Q22. Distance to the trip destination: (m) walking duration: (minutes)

III—Personal assessment of the quality of parking facilities and services

Q23. What is your overall evaluation of the parking location that you chose to park your vehicle?

1. Very satisfied 2. Satisfied 3. So-so 4. Dissatisfied 5. Very dissatisfied

Q24. How do you evaluate the following aspects of the parking facilities and services?

Evaluation Aspect	Very Good	Good	So-So	Bad	Very Bad
Clear visual conditions inside the parking lot	1	2	3	4	5
Design of aisles inside the parking lot	1	2	3	4	5
Convenient maneuver inside the parking lot	1	2	3	4	5
Design of driveway/accessibility to the parking spot inside the parking lot	1	2	3	4	5
Building structure of the parking lot	1	2	3	4	5
Building architectural design of the parking lot	1	2	3	4	5
Floor height of the parking lot	1	2	3	4	5
Size of parking spot	1	2	3	4	5
Parking attendant attitude	1	2	3	4	5
Availability of parking guidance (digital boards, signs)	1	2	3	4	5

Availability of parking spots	1	2	3	4	5
Security cameras inside the parking lot	1	2	3	4	5
Safety equipment in the parking lot	1	2	3	4	5
Parking fee	1	2	3	4	5
Availability of electronic payment system	1	2	3	4	5
Availability of parking application (pre-trip information, booking, payment)	1	2	3	4	5
Walking distance to trip destination	1	2	3	4	5
Parking rules and facilities to ensure vehicles are parked in an orderly way (marking. . .)	1	2	3	4	5
Weatherproofing equipment	1	2	3	4	5
Floor cleanliness	1	2	3	4	5
Design of Entrance and Exit	1	2	3	4	5
Ventilation system inside the parking lot	1	2	3	4	5

IV—Hypothetical scenarios

For car parker only

For Car Parking Duration Less than 2 h	[1] **Illegal On-Street Parking**	[2] **On-Street Parking**	[3] **Off-Street Parking**
Parking fee per turn (VND)	0.0	16.000	40.000
Walking distance (m)	>300 m	<100 m	200–300 m
Weather proofing—roof			Not available
Electronic card for automatic check in/check out			Available
Security camera			Available
Apps for checking vacant spots, parking price		Not available	Not available
Surveillance camera for detecting illegal parking	Not available		
Fine for illegal parking (VND)	400.000		
Choice			
For Car Parking Duration More than 2 h	[1] **Illegal On-Street Parking**	[2] **On-Street Parking**	[3] **Off-Street Parking**
Parking fee for every 2 h (VND)	0.000	30.000	15.000
Walking distance (m)	200–300 m	>300 m	200–300 m
Weather proofing—roof			Not available
Electronic card for automatic check in/check out			Available
Security camera			Not available
Apps for checking vacant spots, parking price		Available	Not available
Surveillance camera for detecting illegal parking	Not available		
Fine for illegal parking (VND)	400.000		
Choice			

For motorcycle parker only

For Motorcycle Parking Duration Less than 2 h	[1] **Illegal On-Street Parking**	[2] **On-Street Parking**	[3] **Off-Street Parking**
Parking fee per turn (VND)	0.000	6.000	4.000
Walking distance (m)	200–300 m	>300 m	100–200 m
Weather proofing—roof			
Electronic card for automatic check in/check out			Available
Security camera			Not available
Apps for checking vacant spots, parking price		Available	Not available
Surveillance camera for detecting illegal parking	Not available		Not available
Fine for illegal parking (VND)	200.000		
Choice			

For Motorcycle Parking Duration More than 2 h	[1] Illegal On-Street Parking	[2] On-Street Parking	[3] Off-Street Parking
Parking fee for every 2 h (VND)	0.000	4.000	4.000
Walking distance (m)	<100 m	<100 m	100–200 m
Weather proofing—roof			Not available
Electronic card for automatic check in/check out			Available
Security camera			Not available
Apps for checking vacant spots, parking price		Not available	Not available
Surveillance camera for detecting illegal parking	Not available		
Fine for illegal parking (VND)	800.000		
Choice			

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