Predictive Logistic Models for Off-Street Parking Policy: Controlling Traffic Volume and Movement

Nahla H. Alaswadko†

Department of Civil Engineering, College of Engineering, University of Duhok, Duhok, Kurdistan Region – F.R. Iraq

Abstract—**The land in city centers is typically used for commercial and industrial purposes, leading to increased traffic congestion. To promote more efficient, sustainable, and accessible land use in city centers, it is necessary to manage incoming traffic flow and travel demands effectively. This can be achieved by implementing appropriate parking policies, which should be predicted carefully to avoid adverse effects on human and economic activities. A case study is conducted in Duhok city, Iraq, aims to estimate the potential responses of city center travelers to reasonable off-street parking restriction policies. Real data were gathered through interviews with a quantitative sample of drivers to assess their reactions to two policies: Increasing parking fees and reducing available parking spaces. The study examines central parkers' socio-demographic and travel characteristics, including origin, trip purpose, timing, parking duration, search time, payment, income, age, and car occupancy. The study presents the results of two binary logistic models used to estimate the probability of implementing new parking policies to alleviate traffic congestion and improve movement. The findings suggest that travelers are more inclined to change their mode of transportation or travel time of day rather than altering their destination or canceling their trip. The findings contribute to the ongoing discourse on sustainable urban development and offer practical solutions for addressing the complex challenges associated with traffic volume and movement control in developing cities. This study aims to contribute to the growing body of knowledge on sustainable urban transportation planning and offer practical recommendations for transportation authorities.**

Index Terms—**City center traveler, Logistic model, Parker travelling decision, Parking policy, Response modeling.**

I. Introduction

To develop suitable sustainable transportation programs in any area, parking policies have an extremely influential role and an effective logic that help road planners and traffic policemen control traffic congestion and transport demand (Fahmy, Nazareth and Dyck, 2021, Kim, 2024). Historically, central areas have been opposed to applying such parking constraint policies due to the belief that urban access is considered essential to the economic achievement of any city center area (Chen, et al., 2021, Mei, et al., 2017 and Nieuwkoop, Axhausen and Rutherford, 2016). The city center traffic congestion problem is often aggravated due to many reasons, such as drivers spending too much time searching for parking spaces and thereby congesting the roads. Furthermore, the total number of parking spaces available has a critical effect on the traffic volume that could reach the central area, and the distribution of these spaces can have an effective impact on the movement of traffic within the city center. Obviously, expanding the number of parking spaces is considered a short-term solution to parking space shortages and traffic congestion problems and may attract additional travelers and create more congestion problems. Therefore, parking can be successfully managed by applying some forms of policies in terms of travel demand management strategies, which include parking cost, parking time limit, taxes, parking spatial distribution, and controlling the number of available parking spaces (Patel, et al., 2023, Wang, et al., 2024). However, parking charge and supply policies are the most actual approaches that affect parker travel decisions, which, in turn, are vital for the regular operation of the traffic volume in any city center (Mei, et al., 2017, Moeinaddinia, et al., 2013, Shiftan and Burd-Eden, 2000). To apply such suitable parking restriction policies in the city center, it is imperative to recognize how travelers are more likely to respond to such new and different parking policies (Nieuwkoop, Axhausen and Rutherford, 2016). Several studies have mentioned that increasing parking supply can help to reduce the parking impedance; still, it can also increase the traffic congestion in and around the area due to more travelers that use their private cars than public transportation to reach the CBD (Franco, 2017, Dowling, et al., 2017, Goulias, et al., 2016, Guo, 2013, Gallo, D'Acierno and Montella, 2011, Manville and Shoup, 2005). A study was conducted by Ding and Yang (2020) to predict travelers' responses to high parking charges using logit models. They adopted a method to predict the consequences of different parking pricing strategies on mode choice responses for various travelers' trip purposes. The higher price is specified due to travel time inconsistency,

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†Corresponding author's e-mail: nahla.alaswadko@uod.ac

which has sound effects on transport policy when applying such new or different parking pricing strategies.

Recent studies on city center parking policies emphasize the need for reform to address inefficiencies, environmental concerns, and social inequities. Donald Shoup's work remains central to these discussions, particularly through his influential publications. His studies highlight the economic, environmental, and urban design consequences of traditional parking policies. Shoup studied how factors including parking time, car occupancy, walking speed, and the value of saving time spent walking affect parking. Furthermore, he underlines that effective parking policies can contribute to more vibrant, equitable, and environmentally friendly cities. Policymakers are encouraged to adopt dynamic pricing, reduce parking minimums, and invest in alternative transportation to create sustainable urban environments (Shoup, 2005, Shoup, 2018, Yoka, 2018, Shoup, 2024).

Furthermore, to sidestep additional traffic congestion and parking demand in the city center of many developed countries, the concept of a park-and-ride policy has been implemented. This concept has been presented by many researchers as a multimodal and intermodal transport policy that aims to rearrange the parking areas from the most valuable and economically important city center urban zones to the bordering areas, even though it proposes such alternative plans for travelers to save time and money. However, the park-and-ride policy might be applicable when the study area is large and there is a manageable, accessible, and virtuous scheduling public transport system (Ortega, Tóth and Péter, 2021, Molan and Simićević, 2018, Yan, Levine and Marans, 2018, Shen, et al., 2017, Zhang, Wang and Sun, 2016, Dijk and Parkhurst, 2014, Aros-Vera, Marianov and Mitchell, 2013, Habib, Mahmoud and Coleman, 2013, Zhang, Wang and Yan, 2009, Syed, Golub and Deakin, 2009, Meek, Ison and Enoch, 2008).

The motivation behind this research lies in the growing need for sustainable urban mobility solutions. With increasing urbanization and the accompanying traffic challenges, understanding and implementing effective parking policies can significantly contribute to reducing congestion and enhancing quality of life in cities. This study aims to estimate binary logistic models to evaluate parking users' responses to two main parking restrictions: an increase in parking prices and a decrease in accessible parking spaces, which will increase parking search time. Duhok city center in the Kurdistan region in the north of Iraq is the case study for this investigation. Its distinct geographic location has caused a lot of transportation to be executed through the city and led to a high density of people and vehicles in its city center. In addition to that, during the past decade, this city has experienced an exceptionally high growth rate in population and vehicles due to people migrating from other cities in Iraq. In 2012, an improvement was carried out in the city center road network by changing the traffic direction of its road links. Consequently, road network efficiency to serve traffic was increased by a slightly decreased volume/capacity ratio, increased average traffic speed, and decreased delay time (Abdullah, 2013). However, so far, no parking restriction policies have been applied to reduce its traffic congestion and to shift people to use public transportation, as there are about 15 routes of public transportation in Duhok city (Khalid, 2011). According to a recent study conducted by Al-Ani (2021), it was determined that the peak hour volume ranges between 3470 and 7250 vehicles per hour, and the estimated level of service is F for Duhok city center routes. This service level indicated that the route operations are with extremely low speeds, adverse signal progression, and high delay. In fact, Duhok city center is now at a stage where it is required to implement such practical parking policies, and there is a need to evaluate the possible effects of such policies without affecting its vitality due to such observable traffic congestion problems, as shown in Fig. 1. This study stands out for its innovative use of SPSS software to develop predictive logistic models for parking policies, with a specific case study of Duhok city center. By analyzing real-world data, it offers localized insights into optimizing parking systems and reducing traffic congestion. The findings emphasize the scalability of such predictive models for developing cities, bridging the gap between theory and actionable urban policy recommendations. In addition, the study provides a roadmap for dynamic pricing and traffic volume control strategies that enhance urban mobility. The remainder of this paper is organized as follows: Section II describes the methodology and data used for modeling requirements. Section III presents the modeling approach used to develop logistic regression models to predict the relationship between the response of parkers to parking policies and the characteristics of parking users. Section IV presents the findings of this study and discusses the implications and potential applications of the results.

II. Methodology for Modeling Requirements

A. Survey of the City Center Area

A Parking Inventory Survey was undertaken to supply all the necessary, information related to parking in Duhok city center, located in the Kurdistan Region of Iraq, as shown in Fig. 2. On-street parking inventory was carried out and indicated that traffic policemen restricted travelers to using on-street spaces. However, very few spaces are available for very specific times of day. These spaces are free of charge and for about 5–10 min only; otherwise, there is a fine applied (USD $25). There are 28 off-street parking locations

Fig. 1. Traffic congestion problem in the study area.

(surface lots, multistory garages, and underground garages), with a total of 4,350 parking spaces in the study area (Fig. 2). Only 35% of these parking locations are public, and the rest are private, all with unrestricted parking duration.

B. Questionnaires Survey of the City Center Travelers

The possible responses to parking restriction policies of city center-bound travelers were carried out by a questionnaire survey. For an interview survey design purpose, the sample size calculator program was utilized to find out the required number of respondents to be interviewed to acquire statistically significant results for developing response models, where this sample size is reflecting the target population of the study area (SSC, 2023). The program is based on two main measures that are relevant to the accuracy of the data and represent the confidence interval and level.

The population size in this study is the number of vehicle spaces in the selected study area, which are 4,350 vehicle parking spaces. Hence, the required representative sample size to be interviewed for the CBD area is 354 respondents based on a 5% confidence interval and a 95% confidence level. The regular proportion of parking spaces used per day (parking space turnover) in Duhok city center was roughly 5.8 vehicles per space per day (Aswad, 2003). Therefore, the number of vehicles occupying parking spaces was expanded to 25,230 (4350 × 5.8) vehicles, which was considered the actual population size, and then the required sample of parking users became 378 respondents. A total of 380 parking users were interviewed in the city center area and were asked a number of inquiries related to their trip, as presented in Table I. In addition, the stated performance part of the survey included the two main questions that drivers have been asked for their probable responses to: Increasing parking fees and decreasing available parking spaces to increase the time to find a parking space.

Fig. 2. Off-street parking facilities in the study area (Duhok city center).

III. Modeling Approach

At present, there are two vital approaches that are being used to develop models in the field of transportation: deterministic and probabilistic modeling approaches. However, the latter models are considered more accurate as they deliberate uncertainties that are related to the explanatory variables (Shtayat, et al., 2022, Justo-Silva, Ferreira and Flintsch, 2021, Abaza, 2021). One of the more common and simple probabilistic models is the binary logistic regression model, which is used for binary classification and to assess the probability of binary responses using one or more predictors. This probability permits that the occurrence of a possibility of such a factor increases the likelihood of a given

TABLE I
Explanatory Variables for Asking Travelers About Their Trip

Explanatory variables	Choices
Origin (region)	
Time needed to arrive	a. 5 min to 15 min b. 15 min to 30 min c. More than 30 min
Driver age	a. Younger than 35 years b. Older than 35 years
Driver income	a. Less than (USD $ 500) b. Between (USD $ 500 and 1000) c. More than (USD $ 1000)
Trip purpose	a. Work b. Shopping c. Other purposes
Expected parking time (duration)	a. Less than 1 h b. Between (1 and 3) h c. More than 3 h
Type of parking payment	a. Paid c. Not paid (free)
Number of person in the car	
Time spent searching for a parking space	a. Less than 10 min b. Between (10 and 20) min c. More than 20 min
Time needed to walk from the parking location to a terminal place	a. Less than 10 min b. Between (10 and 20) min c. More than 20 min
What is your probable response if the parking cost is increased?	a. Not change b. Shift to using public transportation, taxi, or walking c. Switch time of day d. Alter terminal e. Change the trip
What is your probable response if the number of parking spaces is decreased?	a. Not change b. Shift to using public transportation, taxi, or walking c. Switch time of day d. Alter terminal e. Change the trip

outcome by a particular factor. This will help to develop a response model that presents the probability of output in terms of the input variable(s) (Alaswadko, 2016, Wuensch, 2014). In this study, the binary logistic regression model was utilized to predict the probability that a traveler to the city center will change their travel routines according to applying two parking policies: decreasing parking availability and/or increasing parking cost. The logistic regression models were developed to predict the relationship between each of the above two variables, which were considered the predicted variable or dependent variable (the response of parkers to parking policies) and the predictors or independent variables (the characteristics of parking users).

A. Characteristics of Parking Users

Parker Trip Origin and Time Needed to Reach the City Center: The origins of travelers' trips were divided into eight zones. The majority of parking users entered the city center from zones 2 and 1, which are about 20% and 22%, respectively. The lower percentages of parkers were entered from zones 6 and 7. These results indicated that the higher percent of travelers' origins were from the west side of Duhok city and the lower percent were from the east side. The travelers' responses indicated that 57% of drivers needed only 5–15 min to reach their terminal place in the city center. This is followed by 35% of drivers needing 15–30 min, which means that the majority of drivers had a short trip to reach their terminal place.

Parker Age and Income: Drivers were asked about their age within two categories, as some people were not ready to respond about their exact age. The age categories were <35 years or more than 35 years. It was found that slightly over half of the respondents were aged more than 35 years. This means that the study area almost attracts equally many drivers, both older than 35 years and younger than 35 years. The sample was comprised of 58 percent of average drivers' incomes, which were between USD $500 and $1,000; 34% were less than USD $500; and only 8% were more than USD $1,000.

Parker Trip Purpose, Duration, and Type of Parking Payment: Parkers that were destined for the study area were divided into three types according to their purposes, including working trips, shopping trips, and other reasons for trips. The sample consisted of 41% of work trips, which is the highest percentage; 24% of shopping trips; and 35% of other trips. 28% of the respondents were expected to stay in the city center for less than an hour, which was expected to be a short stay, wherase 33% were between an hour and 3 h, and the rest of the respondents were expected to stay for more than 3 h. The last two groups were people who had come to work and expected to have a long stay in the city center. Parking payments were classified as free parking and non-free parking (meaning the driver paid for parking). Only 64% of respondents were paid for parking their cars, and the rest were not paid. Where these latter respondents were parked was mostly in illegal parking spaces. This indicates that the driver could take more time to find available free parking spaces. More than 70% of the worker's trips have long trip duration, whereas less than 10% of non-worker trips have long trip duration, as shown in Fig. 3. Furthermore, the figure shows the classification of parkers' trip purpose by parking payment. The figure shows that the sample was nearly equally divided between paid and non-paid parking. This reflects that there are many illegal parking spaces that drivers can utilize to park their cars in the city center.

Number of People in the Car, Searching Time, and Time Spent: It was found that about 49% of the drivers drove alone, and 25% of the drivers had only one passenger in the car. The rest had more than one passenger in the car. The majority of respondents (90%) spent <10 min searching for parking spaces. This could be due to the high number of available parking spaces in the study area. In addition, 89% of travelers can reach their terminal in <10 min after parking their cars. Out of 380 respondents, 337 of them show short walking time, and only 43 of them show long walking time.

B. Response of Parkers to Parking Policies

Increase in parking cost

Fig. 4 presents the results of stated responses to an increase in parking cost and shows that 47% of users would never discontinue coming into the city center, no matter how much parking it will cost. About 36% of parking users would shift to using public transport. However, there are a small number of parkers who chose the other options.

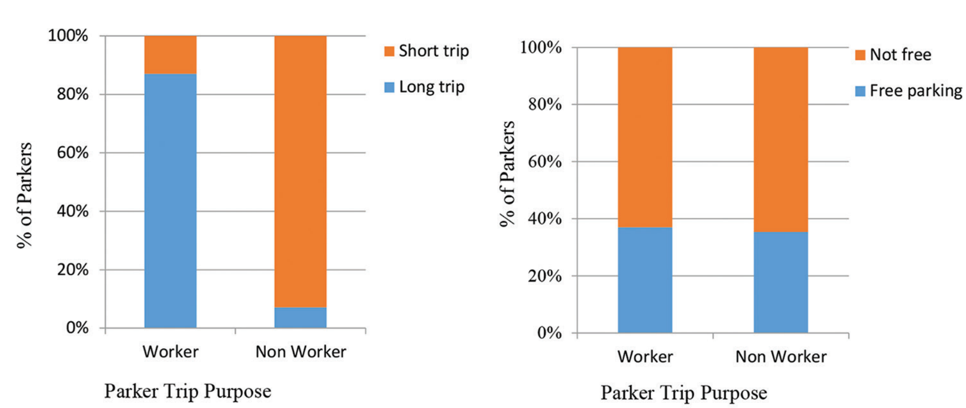

Fig. 3. Classifications of parkers' trip purposes by trip duration and parking payment.

These results indicate that increasing parking costs can be a good policy to reduce traffic congestion. A virtuous parking policy encourages people to shift modes of travel, use public transport facilities, or switch the time of day. These options will lead to decreased traffic congestion without decreasing the number of travelers to the city center (i.e., not reducing the vitality of the city center); they will also discourage people from canceling their trips to the city center. Therefore, the travelers’ travel decisions were categorized into two groups. First, the positive change, which comprises no changes in travelers’ travel decisions or changes in mode or time of day, Second, the negative change, which comprises alterations in terminal locations or canceling the trips, Fig. 4 also shows that the percentage of parkers who responded to the positive change was higher than the negative change. This indicated that the increase in parking prices would not significantly affect the attractiveness of the central area.

Decrease in parking supply

Fig. 5 shows that the percentage of users that would continue coming into the city or shift to using public transport was significantly higher than other options. This indicates that the percentage of parkers who responded to positive change was higher than the percentage of parkers who responded to negative change. Therefore, these results specify that the policy of decreasing parking supply can be a good policy to reduce traffic congestion without affecting the vitality of the center and causing travelers to move out of the city center.

C. Binary Logistic Models

Binary logistic regression models were estimated to predict the probability that parkers to the city center will change their travel behaviors according to applying the two suggested parking policies. The analysis process was conducted using the Statistical Package for the Social Sciences (SPSS) (SPSS, 2023). The two categorized travelers’ travel decisions (positive and negative changes) were considered dependent variables to predict the probability of applying parking policies. The logit link function of the odds in logistic regression is signified by (υ) and serves as the dependent variable for the model. In a binary regression model, the logit is the natural logarithm of the odds that a circumstance arises for a specific event (Justo-Silva, Ferreira and Flintsch, 2021, Huang, et al., 2019, Alaswadko, et al., 2019, Alaswadko, 2017, Wuensch, 2014). In this study, the event is applying parking policies due to positive changes in parking users’ behavior. The general form of this model is described below (1 and 2):

$$\upsilon = \ln [\text{odds (positive change)}] \quad (1)$$

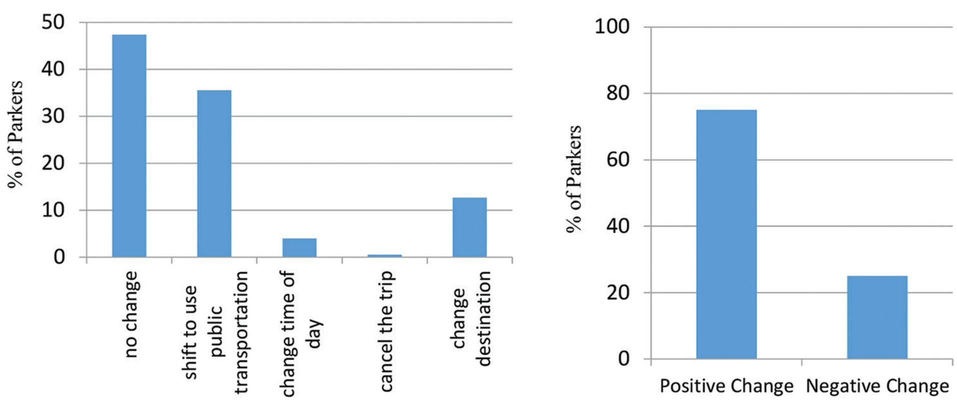

Fig. 4. Stated responses to the increase in parking costs.

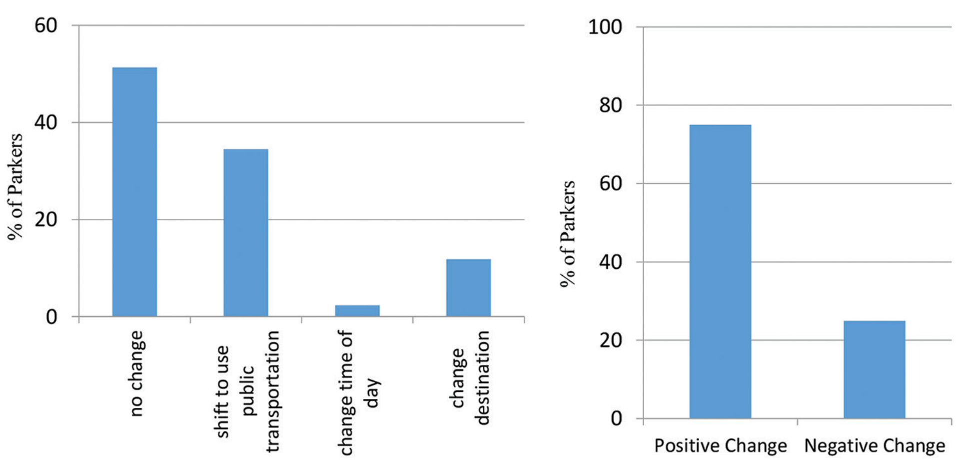

Fig. 5. Stated responses to a decrease in parking supply.

TABLE II
The Results of the Predicted Binary Model Increase Parking Costs

Explanatory variables	Coefficients (β)	Standard error	Wald	df	Sig. p-value*	Odds ratio	95% confidence interval limits	
							Lower limit	Upper limit
Intercept	1.817	0.785	5.363	1	0.021	6.152		
Trip origin	−0.134	0.070	3.723	1	0.049	0.874	0.763	1.002
Arrival time	−0.394	0.191	4.260	1	0.039	0.675	0.464	0.980
Income	−2.073	0.275	56.615	1	0.000	0.126	0.073	0.216
Trip purpose	0.340	0.153	4.916	1	0.027	1.405	1.040	1.898
Parking payment	0.836	0.269	9.662	1	0.002	2.306	1.362	3.905
Time searching	1.119	0.395	8.019	1	0.005	3.062	1.411	6.641

*: All variables are statistically significant (p<0.05) at 95% of confidence level

$$\upsilon = ln\ [\frac{probability\ of\ \ positive\ change}{probability\ of\ negative\ change}] \quad (2)$$

Where: ln is the natural logarithm: The probability of positive change of parkers' travelling decision can be obtained by the predicted log-odds using the following formula (3):

$$\text{The probability of positive change } = \frac{1}{1+exp\ (-\upsilon)} \quad (3)$$

The log-odds (υ) can be determined from the linear combination of contributed predictors.

Binary model for an increase in parking cost

The results of the binary logistic regression model for the sample used herein are shown in Table II. The second column in the table presents the estimated coefficient (B) for each variable. It can be seen that all variables are not included in the model because the insignificant variables are eliminated based on significant values ($p < 0.05$). The model is statistically significant, and each included variable has a significant coefficient with an odd ratio (exp B) value, which is an amount of the range in event odds resulting from a unit change in the variable within the lower and upper limits of the 95% confidence interval (Hosmer and Lemeshow, 2013). The constant value (i.e., intercept) is the predicted probability of positive change when the effects of all other variables in the model are assessed at zero. Accordingly, see (4):

The predicted probability of positive change is

$$= \frac{1}{1+exp\ (-\upsilon)} = \frac{1}{1+exp\ (-1.817)} = 0.86 \quad (4)$$

Consequently, about 86% of respondents within the city center were expected to see positive changes in parking users' behavior during the period of the study. Nonetheless, the average probability of negative changes was 14% ([1–0.86] × 100). The odds of positive changes were defined as the ratio of the probability of positive changes over the probability of negative changes. In that regard, the odds for positive changes were 6 (0.86/0.14), that is, the odds of positive changes in parkers' travel decisions with an increase in parking costs were 6 to 1. The effect of each variable, as shown in Table II, is as follows: Trip origin has a negative significant coefficient value and indicates that people coming from the west side of Duhok city are more likely to change their travel decision. Time needed to arrive has a negative significant coefficient value and indicates that people who have a long trip to reach their terminal are more likely to change their travel decision. Income has a negative significant coefficient value and indicates that travelers with more income are less likely to change their behaviors when parking prices increase. Trip purpose has a positive significant coefficient value and indicates that non-worker travelers are more likely to change their behaviors than worker travelers. Parking payment has a positive significant coefficient value and indicates that those who paid for parking are more likely to change their travel decisions as they are the most likely to need parking. Time needed for searching a park has a positive significant coefficient value and indicates that those who spend more time searching a park are more likely to change their travel decision. The developed logistic model can be evaluated by testing classification accuracy. The aptitude of the model to correctly forecast positive changes in parkers travel decisions due to applying the suggested policies is tested using cross-tabulation analysis. The frequency distribution of the estimated and observed changes in travel decisions due to such applied policies is displayed as a table in matrix format (Wuensch, 2014). Hence, to evaluate the success rate of the predicted logistic model, the numbers of respondents that are being correctly or incorrectly anticipated are determined. The cross-tabulation table shown in Table III is used to evaluate the accuracy of the estimated model and shows that 75% of the observed respondents are correctly assigned to the probability of applying the policy of increasing parking costs.

TABLE III
Correctly Estimated Results of the Predicted Binary Model to Increase Parking Costs

Observed	Estimated		
	Increase parking cost		Percentage correction
	No change	Change	
Increase parking cost			
No change	140	39	78.2
Change	55	145	72.5
Overall percentage			75.2

TABLE IV
The Results of the Predicted Binary Model to Decrease Parking Supply

Explanatory variables	Coefficients (β)	Standard error	Wald	df	Sig. p-value*	Odds ratio	95% confidence interval limits	
							Lower limit	Upper limit
Constant	0.288	0.797	0.131	1	0.018	1.334		
Origin	−0.142	0.068	4.420	1	0.036	0.867	0.759	0.990
Arrival time	−0.491	0.195	6.353	1	0.012	0.612	0.418	0.897
Age	−0.757	0.258	8.579	1	0.003	0.469	0.283	0.779
Income	−0.951	0.254	14.001	1	0.000	0.386	0.235	0.636
Trip purpose	0.442	0.153	8.310	1	0.004	1.556	1.152	2.102
Parking payment	1.363	0.266	26.257	1	0.000	3.908	2.320	6.582
Time searching	0.944	0.383	6.079	1	0.014	2.571	1.214	5.445

*: All variables are statistically significant ($p<0.05$) at 95% of confidence level

TABLE V
Correctly Estimated Results of the Predicted Model to Decrease Parking Supply

Observed	Estimated		
	Decrease parking supply		Percentage correction
	No change	Change	
Decrease parking supply			
No change	150	45	76.9
Change	53	131	71.2
Overall percentage			74.1

Binary model for decrease in parking supply

Table IV demonstrates the results of the binary logistic regression model for the responses of decreasing parking supply. The significant coefficients are the same as in the increasing cost model and have the same signs. However, the driver's age is also significant and has a negative coefficient, indicating that younger people are more likely to change their manners. The constant value is the predicted probability of positive change when the effects of all other variables in the model are assessed to be zero. Hence, the predicted probability of a positive change for a decrease in parking costs is 0.57. Thus, about 57% of respondents within the city center were expected to see positive changes in parking users' behavior during the study period. Even so, the probability of negative changes was 43% ([1–0.57] × 100). Therefore, the odds for positive changes over negative changes were 1.3 (0.57/0.43), that is, the odds of positive changes in parkers' travel decisions with decreasing parking supply were 1.3–1. For evaluating the model's accuracy, Table V shows the accuracy of the estimated model and demonstrates that 74% of the observed respondents are correctly assigned to the probability of applying the policy of decreasing parking supply.

IV. Conclusions and Anticipated Recommendations

In urban areas worldwide, managing traffic volume and movement is an ongoing challenge with significant implications for city infrastructure, environmental sustainability, and quality of life. Predictive logistic models have emerged as powerful tools in this domain, offering the ability to forecast and optimize parking policies to efficiently control traffic volume and movement. This case study explores the application of predictive logistic models to addressing parking policy challenges within urban environments. By leveraging data-driven insights and advanced analytical techniques, cities can proactively design and implement parking policies that mitigate congestion, reduce emissions, and enhance the overall urban experience. Through a detailed examination of real-world scenarios and outcomes, this study sheds light on the efficacy of predictive logistic models in shaping parking strategies and optimizing traffic management efforts. The majority of users entering Duhok city center from the west require a short time to reach their destination. They typically have average incomes, are on work-related trips, drive alone, pay for parking, spend a short time searching for parking spaces, have long durations of stay, and can reach their destination within a short walking distance. The percentage of parkers who respond positively to an increase in parking costs is higher than that of those who respond negatively, indicating that increasing parking prices would not significantly affect the attractiveness of the central area. Similarly, the percentage of parkers who respond positively to a decrease in parking supply is higher than that of those who respond negatively, suggesting that reducing parking supply could effectively reduce traffic congestion without diminishing the vitality of the center or causing travelers to move out of the city center. Individuals with longer trip times to reach their destination are more open to changing their travel decisions. Moreover, travelers with higher incomes are typically less inclined to accept changes in their activities due to parking restrictions. Non-workers are more likely to change their behavior than workers, whereas those who pay for parking are more likely to alter their travel decisions, increasing their need for parking. In addition, individuals who spend more time searching for parking are more likely to change their travel plans, and younger people are more likely to do so than older individuals. Seventy-five percentages of observed respondents are correctly assigned to the probability of applying the policy of increasing parking costs, whereas 74% are correctly assigned to the probability of applying policies to decrease parking supply. This study recommends implementing the presented parking policies to reduce traffic congestion in Duhok city center. The benefits of these policies include reducing travel time, lowering costs for some users, improving city center amenities, boosting economic activities, decreasing air pollution, reducing energy consumption, increasing productive land use, and decreasing the necessity to expand roads. Through a comprehensive review of existing literature and empirical evidence, this case study aims to contribute to the growing body of knowledge on sustainable urban transportation planning and offer practical recommendations for policymakers, city planners, and transportation authorities.

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