Evaluation of the Impact of Land Use on On-Street Parking Demand: A Case Study of Ximen Road, Tainan City

Yao-Wen HSU [a], Tzu-Chang LEE [b]
[a] *Department of Urban Planning, National Cheng Kung University, Tainan, 70101 & Bureau of transportation, Tainan City Government, Tainan, 70801, Taiwan; E-mail: chinyan@mail.tainan.gov.tw*
[b] *Department of Urban Planning, National Cheng Kung University, Tainan, 70101, Taiwan; E-mail: jtclee@mail.ncku.edu.tw*

Abstract: Tainan City is one of Taiwan's early-developed cities, characterized by mixed land use, which affects parking demand. This study aims to understand the relationship between on-street parking demand and land use in Tainan City. Using on-street parking fee data from March 2023, the study applies a Markov Chain Monte Carlo (MCMC) model with a binomial distribution to analyze the correlation between land use factors and the number of parking tickets issued. Empirical data show that commercial and residential land use exert different levels of influence. The results suggest that government agencies could implement stricter parking regulations for commercial areas to curb parking spillover.

Keywords: On-street parking spaces, parking demand, land use, Markov Chain Monte Carlo (MCMC) method

1. INTRODUCTION

Tainan City is one of Taiwan's early-developed cities, characterized by its unique historical landscape and street patterns. To this day, it retains many features of early urban planning. In recent years, the cost of owning and using private vehicles has gradually decreased, leading to an increase in household vehicle usage and, consequently, parking-related challenges. In *Paved Paradise: How Parking Explains the World*, Henry Grabar explicitly points out that parking issues result in wasted urban space and contribute to various social problems and risks to life and property (Grabar, 2024). Without effective management, on-street parking not only encroaches on road space but also reduces the efficiency of public space usage due to occupancy of long duration.

In Taiwan, on-street parking spaces are designated based on geometric

assessments of the roadway, ensuring that parking does not compromise traffic flow or safety. Off-street parking is provided through planned urban parking facilities and incentivized development on private land. For buildings, the provision of parking spaces is governed by the Building Technical Regulations, urban planning land use control guidelines, and Traffic Impact Assessment on Buildings and Structures. These regulatory instruments require developers to quantitatively estimate the parking demand likely to be generated by the proposed land use—whether residential, commercial, or other trip-generating developments—and to provide sufficient parking on-site. This ensures that parking demand is internalized within each development project, thereby reducing dependence on public on-street parking resources.

Land use and development generate various parking demands. In recent years, urban planners and transportation planners have sought to internalize parking demand within buildings through different approaches. However, conservative parking demand evaluations and financial constraints have led to continuous spillover, making it difficult for on-street parking spaces to be effectively accommodated.

A study on transportation policy in Victoria, Canada highlights that in high-density commercial and residential areas, urban planners should account for future parking demand by allocating 20–30% of land area for roads or parking (Litman, 2022). This aligns with Henry Grabar's argument that urban space is often displaced due to parking needs. In Taiwan, parking demand generated by various commercial and residential activities is largely met through on-street parking. According to statistics from the Ministry of Transportation, from 2011 to the third quarter of 2024, the number of on-street parking spaces has increased by approximately 10,000. This indicates that more road space has been designated for parking, which not only lowers the level of service for roads but also reduces the availability of pedestrian space.

The advantage of on-street parking is that drivers can decrease their time costs by approaching their destinations more conveniently, enjoying higher accessibility and availability while reducing the time spent searching for parking and walking. However, the provision of on-street parking also brings several inconveniences. Without effective management policies, this can result in longer travel times, increased air pollution, and a heightened risk of accidents. It can disrupt access routes for residential and commercial activities, and long-term occupancy, prolonged parking, or even abandoned vehicles can negatively impact the urban environment and pose challenges for emergency response (Shen et al., 2020). In a mixed-traffic flow environment, the interaction between on-street parking maneuvers and mainline traffic increases the risk of traffic accidents (McAndrews, 2020).

Parking management policies are a crucial aspect of private vehicle regulation. Many studies suggest that implementing strict parking regulations to increase the cost

of private vehicle use can effectively discourage its usage. However, without strong scientific foundations, these policies often lack sufficient credibility and fail to gain widespread support. Research has also shown that parking facility usage characteristics are closely related to local land use (Marsden, 2006). Analyzing the relationship between land use and on-street parking patterns can help clarify parking demand under different land use scenarios. Additionally, insights from empirical data analysis can provide urban planners and transportation managers with clearer strategies for policy development.

Owing to technological limitations, accurately capturing on-street parking demand has long been a challenge, resulting in relatively few studies on this topic in recent years. This study leverages parking fee transaction records and geolocation data provided by the Bureau of Transportation, Tainan City Government for March 2023, integrating these with a GIS database to examine land use characteristics surrounding on-street parking spaces. By analyzing the relationship between parking activity and surrounding land use types, the study aims to better understand fluctuations in on-street parking demand under varying land use conditions. The findings offer valuable insights for urban planners and transportation policymakers in formulating parking control strategies for different zoning areas, and also provide recommendations for the integrated management of on-street and off-street parking facilities.

2. METHODOLOGY

This section begins with an overview of the study area, followed by a description of the research hypotheses and model construction. Finally, the data processing procedure is detailed.

2.1 Research Area

Ximen Road is one of the main arterial roads in Tainan City, running north to south with a total length of 6.7 kilometers. It is divided into four sections, passing through three administrative districts, each exhibiting distinct land use characteristics.

Section 4 of Ximen Road is in North District, primarily consisting of residential land use, followed by mixed residential-commercial use. Section 3, also in North District, features diverse land use types, with a high proportion of commercial areas, along with some educational and institutional facilities, as well as a significant share of mixed residential-commercial use. Section 2, situated in Central West District, is predominantly commercial, with surrounding medical institutions, shopping streets,

and historical commercial zones. Notably, two traffic circles in this section have been designated as parking lots, classified as off-street parking in the system. Section 1 falls within South District, with Jiankang Road serving as the dividing line—its northern part features a high density of commercial buildings and department stores, while the southern part comprises the residential area of the Shuijiaoshe Redevelopment Zone.

Figure 1 illustrates the distribution of on-street and off-street parking spaces within the study area. Red markers represent on-street parking spaces, which are geolocated using latitude and longitude data provided by the Bureau of Transportation, Tainan City Government. Green markers indicate off-street parking spaces, mapped using the bureau's base data combined with a GIS system.

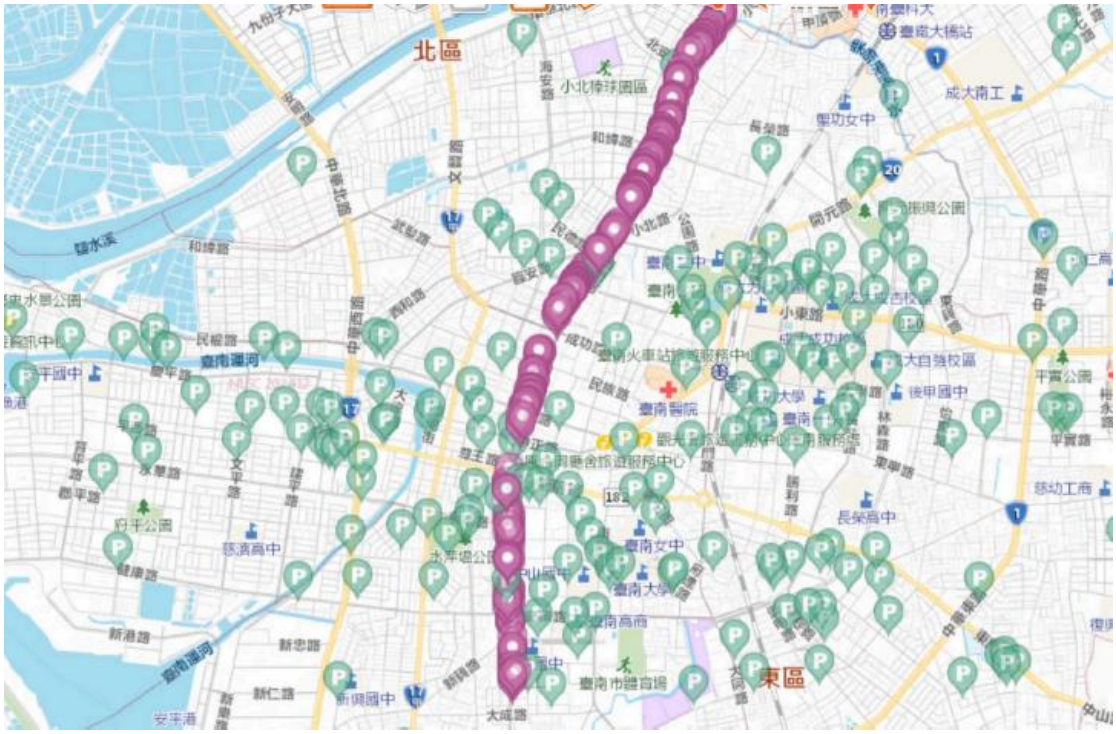


Figure 1 Study Area and Parking Space Distribution

2.2 Model Construction

The on-street parking fee collection in Tainan City follows a 60-minute patrol system, operating daily from 8:00 AM to 10:00 PM, with a maximum of 14 ticketing rounds per day. When a parking attendant arrives at Parking Space A, if a vehicle is present and a ticket is issued, it is considered a successful trial; otherwise, it is a failed trial. Over 14 trials, the results are represented as a series of 1s (success) and 0s (failure), which aligns with the assumptions of a binomial probability distribution.

In this study, parking demand is assumed to be correlated with land use. Based on this, the research model is formulated as Equations (1) and (2). This formulation

ensures the predicted probability remains within (0,1) and aligns with standard practice in logistic modeling.

$$y_i \sim binomial(p_i, 14) \quad (1)$$

$$logit(p_i) = \ln\left(\frac{p_i}{1-p_i}\right) = f(landuse_i) \quad (2)$$

where,

y_i: *Number of parking ticket issuances,*

i: *On-street parking lot,*

p_i: *Probability of parking ticket issuance during a specific hour.*

Regarding the research assumptions, land use types (commercial, educational, or residential) are considered to have a significant impact on parking demand and parking duration. Commercial areas are associated with high parking demand and short parking duration (Deo Chimba, 2012), whereas residential areas may exhibit varying parking patterns depending on the type of housing (Al-Sahili & Hamadneh, 2016; Parmar et al., 2021).

Additionally, the competitive relationship between off-street parking facilities and on-street parking demand is also expected to influence parking behavior. Furthermore, studies have suggested that in areas with more efficient public transportation services, parking demand may decrease as a result (Peng et al., 2023). Healthcare land use is also considered to have a certain impact on on-street parking demand. However, parking needs may vary depending on different types of medical activities (Dave et al., 2019).

Land use definitions vary across cities, and relying solely on urban planning zoning classifications may provide a simplified approach. However, in Tainan City, such classifications may not accurately reflect actual land use conditions, potentially leading to bias due to the prevalence of mixed-use developments. Many studies suggest that building usage characteristics should be used instead of zoning classifications (Al-Masaeid et al., 1999; Al-Sahili & Hamadneh, 2016).

Regarding the relationship between land use and parking demand, most studies suggest that multiple linear regression models provide a high level of explanatory power. A few studies, however, employ logistic regression, gradient decision tree models, or neural network theories (Al-Masaeid et al., 1999; Dave et al., 2019; Parmar et al., 2021).

Therefore, in this study, land use variables are designed based on the classification system from the Taiwan Map Service System of the National Land Surveying and Mapping Center. The categories are further refined into government offices, school

properties, healthcare facilities, commercial and industrial uses, and residential areas within 70 meters of the on-street parking space. Building on the findings of previous studies, this research adopts the number of registered addresses as an independent variable to represent land use. Assuming a linear relationship between land use and parking demand, the model is applied to the aforementioned binomial distribution framework for analysis. Accordingly, the research model can be summarized as Equation (3).

$$f(landuse_i) = a_0 + a_1 land_i + a_2 off_i + a_3 edu_i + a_4 hos_i + a_5 com_i + a_6 res_i + a_7 prk_i + a_8 bus_i \quad (3)$$

where,

$land_i$: Number of special landmarks,
off_i: Number of institutional facilities,
edu_i: Number of educational and institutional facilities,
hos_i: Number of medical institutions,
com_i: Number of commercial building addresses,
res_i: Number of residential building addresses,
prk_i: Number of off-street parking spaces available,
bus_i: Number of public transportation routes, and
a_0 - a_8: Coefficients of the independent variables.

2.3 Data Acquisition and Processing

Traditionally, recording license plates has been a common method for assessing parking demand. However, recent advancements in license plate recognition technology and information and communication systems have enabled parking ticket issuance records to serve as a more efficient alternative. By leveraging these records, parking demand can be analyzed without the need for direct field surveys, reducing labor costs and potential observational errors (Dave et al., 2019).

In this study, parking ticket issuance records were obtained through collaboration with the Bureau of Transportation, Tainan City Government. From the 2023 dataset, records from March were selected for analysis, totaling 29,288 issuance instances. March was chosen as the study period because it does not include consecutive holidays or school vacation periods, ensuring a more accurate representation of Tainan's typical parking demand.

To refine the dataset, adjustments were made to account for changes in on-street parking space availability. On-street parking spaces are frequently modified due to daily

activities, such as being removed, converted into motorcycle parking, or designated as loading zones. To ensure data accuracy, Google Maps' historical street view feature was utilized to identify and exclude parking spaces that no longer exist. Additionally, records with incorrectly assigned parking space codes were removed. After these refinements, a total of 292 valid parking spaces remained for analysis.

Moreover, since on-street parking fees may be temporarily suspended due to community events or administrative adjustments, days without any recorded fee collections were excluded. As a result, out of the 31 days in March, 24 days of valid ticket issuance records were selected, totaling 7,008 issuance instances.

As previously mentioned, considering the land use characteristics of Tainan City, this study categorizes land use into six types based on building address classification: landmark facilities, educational and institutional facilities, medical institutions, commercial building addresses, and residential areas.

Following the findings of Tainan City's comprehensive transportation system planning survey, the analysis scope for each on-street parking space is defined by a 70-meter walking radius, within which the surrounding land use is examined. Additionally, public transportation accessibility is incorporated into the analysis by considering the number of bus routes and nearby bus stops.

For off-street parking facilities, a service radius of 200 meters is used to assess parking supply. This variable is set based on the evaluation principles for off-street parking spaces in urban planning reviews. The results of data processing are presented in Table 1.

Table 1 Data Filtering and Adjustment Results (Partial)

lacCode	*Date*	*billamount*	*land*	*of*	*edu*	*hos*	*com*	*res*	*prk*	*bus*
0203-055	301	4	0	0	0	0	17	4	6	14
0201-014-2	301	0	0	0	1	0	17	33	0	3
0201-008-6	301	0	0	0	0	0	12	31	0	0
0206-107-2	301	3	0	0	0	0	41	72	15	3
0208-229	301	1	0	0	0	0	22	13	26	5
0201-013	301	0	0	0	0	0	38	19	30	3
0203-057	301	7	0	0	0	0	15	3	6	14
0208-255	301	5	0	0	0	0	16	8	15	0
0207-152	301	7	1	0	0	0	45	35	0	0
0209-393	301	3	0	0	0	0	26	92	0	1
0208-267-1	301	1	1	0	0	0	13	7	15	0
0201-008-7	301	0	0	0	0	0	12	32	0	0

3. RESULT AND DISCUSSION

3.1 Results

In March 2023, parking ticket issuance was conducted 14 times per day across 292 on-street parking spaces. Over 24 days, a total of 7,008 trials were recorded. The most frequent daily ticket issuance counts were three and four tickets per space, occurring 1,177 and 1,164 times, respectively. The highest recorded issuance was 11 tickets in a single day, while no instances of 12, 13, or 14 tickets were observed. Additionally, there were 624 instances where no tickets were issued throughout the day (i.e., failed trials). The average daily ticket issuance per parking space was 3.51, indicating that, on average, 3.5 vehicles occupied each space per day. As shown in Figure 2.

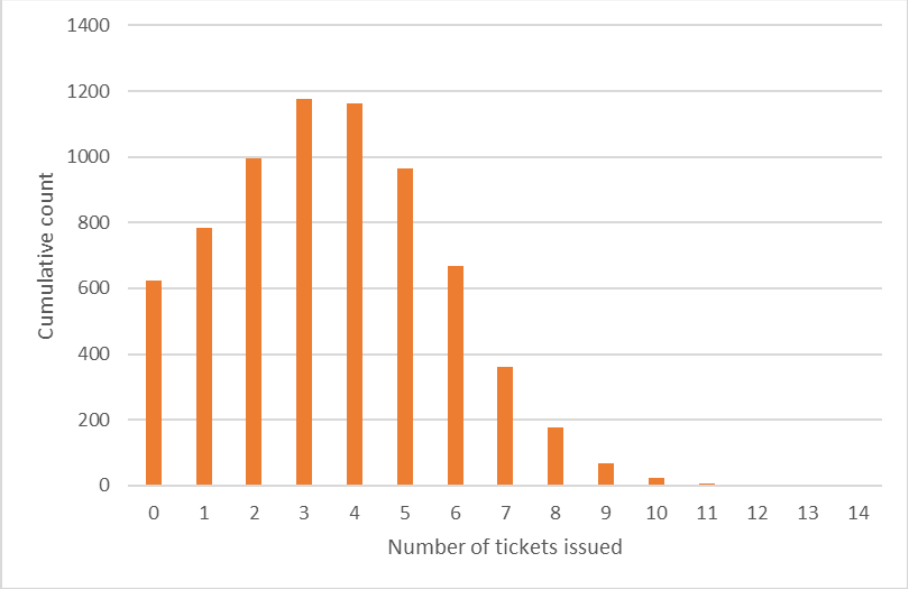


Figure 2 Histogram of Parking Ticket Issuances in March,2023

This study utilized WinBUGS 14 software to estimate a binomial distribution model using the Markov Chain Monte Carlo (MCMC) method. Based on the parameter estimation results from Equations (2) and (3), the model achieved convergence. A total of three Markov chains were run, each with 156,000 iterations. The calibration results are presented in Table 2.

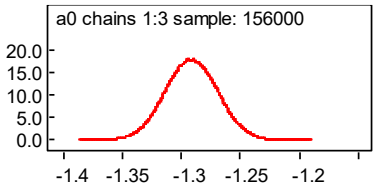
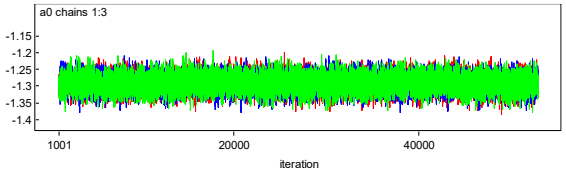
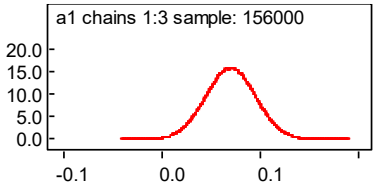
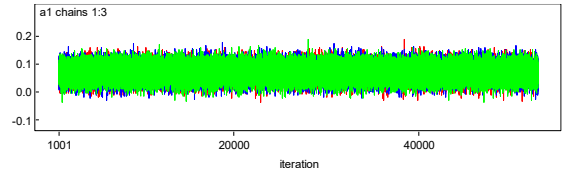
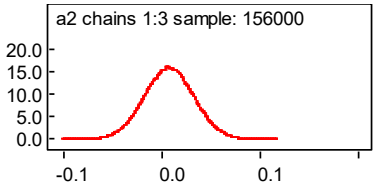
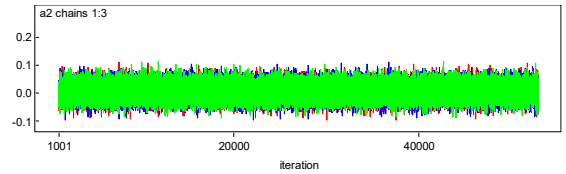
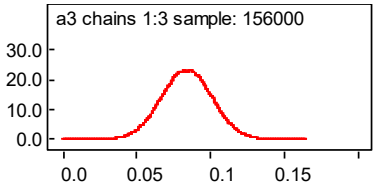
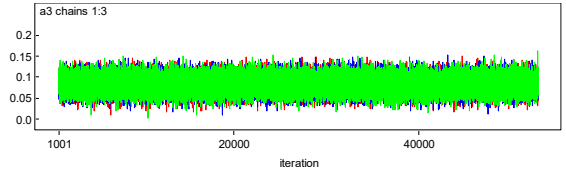
In the parameter calibration results, the estimated coefficients for special landmarks, government institutions, and public transportation routes include zero within their credible intervals. This suggests that the land use associated with special landmarks and government institutions does not have a statistically significant effect on on-street parking demand. Similarly, the number of public transportation routes shows no significant impact, indicating that public transit services may not substantially

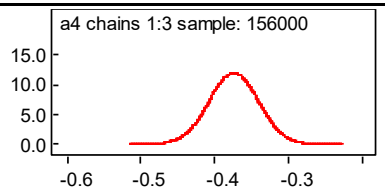
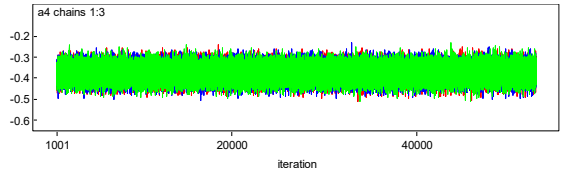
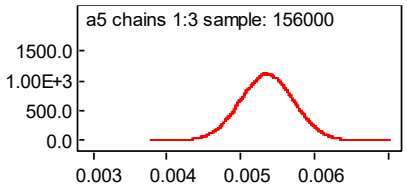
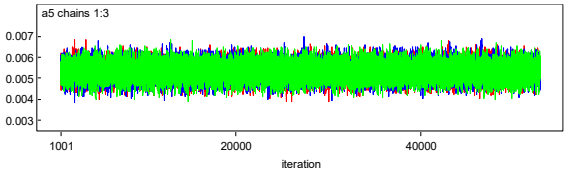
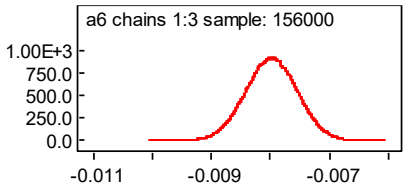
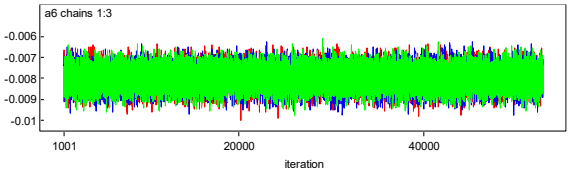
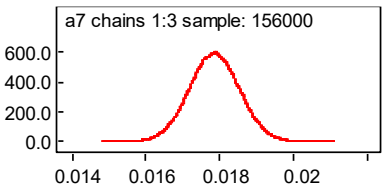
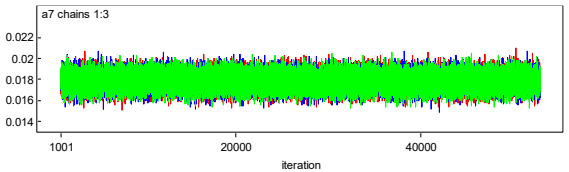
influence on-street parking behavior in the study area.

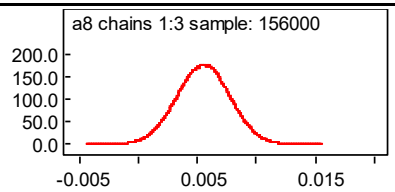
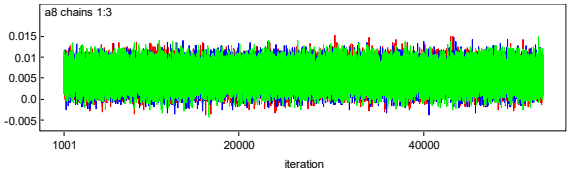
Land use for educational and institutional facilities and medical institutions has a significant impact on on-street parking demand. The influence of educational and institutional facilities is positive, while that of medical institutions is negative. This is because educational and institutional facilities, due to safety considerations, provide limited on-campus parking spaces, leading to an overflow of parking demand that relies on on-street parking. In contrast, medical institutions generally offer sufficient parking facilities. Since most trips to medical institutions are solely for medical purposes, parking demand is sufficiently accommodated internally, reducing the need for external parking supply. This finding differs from previous studies that suggested a significant spillover effect in parking demand around medical institutions (Caicedo et al., 2016). The impact of commercial land use on on-street parking demand is consistent with previous research, showing a significant positive relationship. This indicates that the parking demand in commercial areas of Tainan City heavily relies on external parking supply, highlighting the severity of the issue and the necessity for stricter regulatory measures.

Notably, the impact of residential land use on on-street parking demand is significantly negative. This suggests that under strict parking regulations, residential areas have successfully internalized their parking demand (Weinberger, 2020), reducing reliance on external parking spaces and effectively mitigating previous parking overflow issues.

Table 2 Calibration results of the binomial distribution model.

Parameter	Mean	S.D.	Posterior Density	Trace
a_0 (Intercept)	-1.2920	0.2203		
a_1 (Special Landmark)	0.0697	0.0251		
a_2 (Institutional Facilities)	0.0071	0.0250		
a_3 (Educational and Institutional Facilities)	0.0834	0.0171		

Parameter	Mean	S.D.	Posterior Density	Trace
a_4 (Medical Institutions)	-0.3749	0.0333		
a_5 (Commercial Building)	0.0053	0.0004		
a_6 (Residential Building)	-0.0080	0.0004		
a_7 (Off-Street Parking Spaces Available)	0.0178	0.0006		

Parameter	Mean	S.D.	Posterior Density	Trace
a_8 (Public Transportation Routes)	0.0055	0.0022		

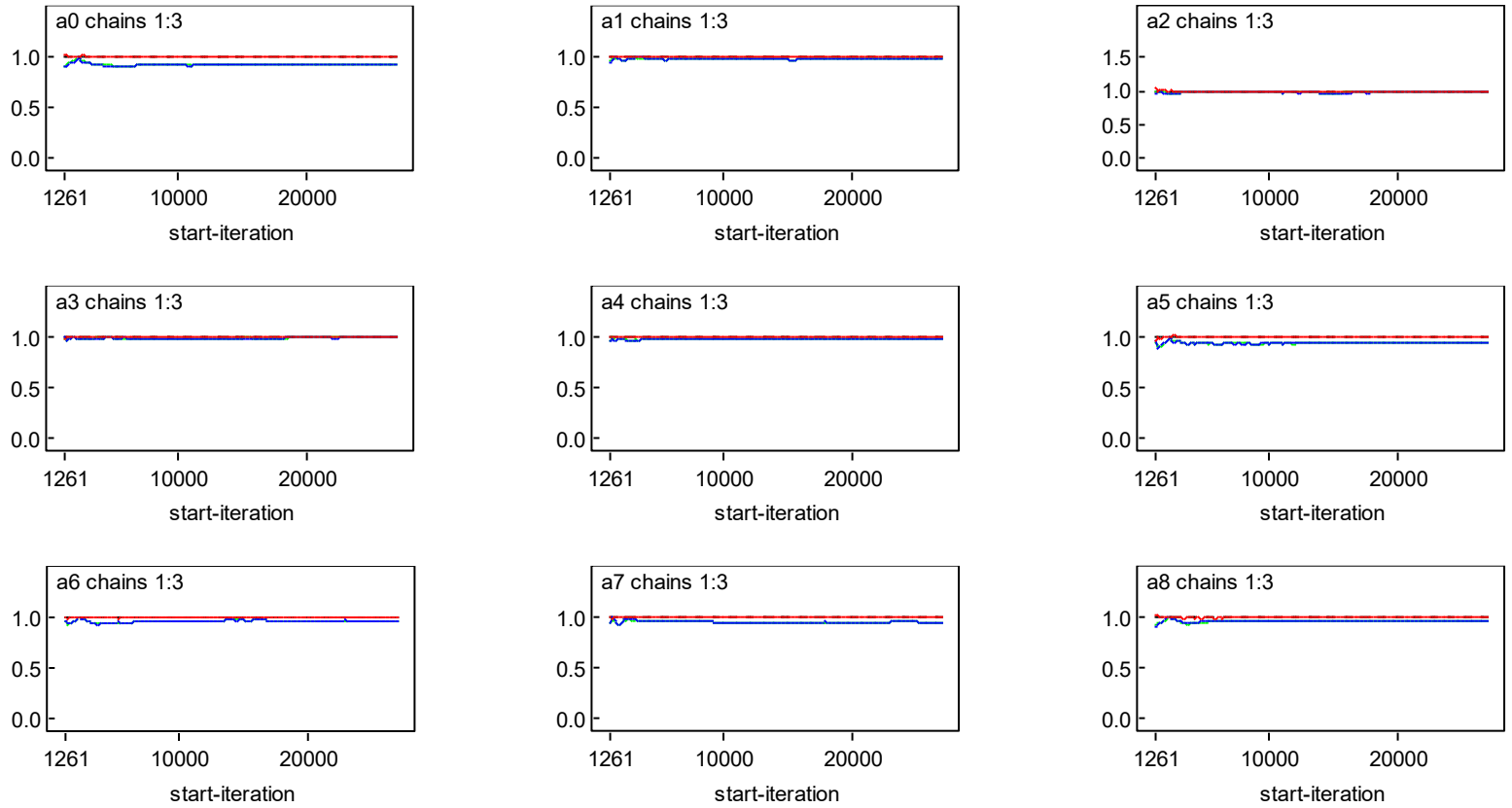
The final aspect to consider is the competitive relationship between off-street parking facilities and on-street parking. The estimation results indicate that while the coefficient is statistically significant, its positive value suggests an unexpected outcome. This can be attributed to the fact that off-street parking facilities are generally established in areas with high parking demand.

When off-street parking fees are similar to those of on-street parking, users tend to have a lower preference for off-street parking (Kobus et al., 2013). Instead, they favor on-street parking spaces that provide more convenient access to their destinations. Another possible reason is that many off-street parking facilities operate primarily on a monthly rental basis, limiting their availability for short-term users, who then opt for on-street parking instead. Taking Ximen Jiankang Parking Garage as an Example. This parking garage completed in 2022, provides 101 parking spaces. The parking fee is the same as on-street parking spaces; however, it is charged throughout the day. In comparison, on-street parking spaces are only charged for a maximum of 14 hours, making them relatively cheaper. Therefore, for residents in the surrounding area, off-street parking—offering greater accessibility and relatively lower daily fees—naturally becomes a more attractive option. This finding is consistent with the model results, which suggest that when off-street parking lacks price competitiveness, its ability to divert demand from roadside parking remains limited.

3.2 MCMC Convergence Assessment

The convergence of the MCMC chains was assessed using the Brooks–Gelman–Rubin (BGR) diagnostic, and the results for each parameter are presented in Table 3. As shown in Table 3, the three Markov chains reached convergence after 156,000 iterations. No individual chain showed significant deviation from the others, indicating that chains with different initial values converged to the same target posterior distribution. Overall, the three chains consistently demonstrated convergence. Additionally, the Gelman–Rubin diagnostic values for all parameters approached 1, confirming adequate convergence of the parameters. This convergence assessment is further supported by trace plots and density plots.

Table 3 Calibration results of Brooks–Gelman–Rubin (BGR) diagnostic



4. MODEL APPLICATION AND VALIDATION

This study focuses on Ximen Road in Tainan City, an urban corridor characterized by a mix of residential and commercial land uses, including large-scale commercial developments. The objective is to explore the relationship between land use configurations and on-street parking demand, with particular attention to the extent to which land development induces parking spillover effects onto public streets. By identifying spatial patterns of demand, the study seeks to inform regulatory approaches that internalize parking needs within developments through appropriate zoning controls and building regulations.

To evaluate the portability of the model, parking fee data from Minsheng Road—another major corridor in Tainan City—was used for validation. Minsheng Road serves as an east–west arterial connecting the West Central District and Anping District, spanning approximately 1.9 kilometers and containing 90 on-street parking spaces. The corridor is primarily composed of low-intensity commercial developments along the street frontage, complemented by residential areas, one medical facility, and two schools.

According to the observed data from March 2023, a total of 2,553 records were collected from Minsheng Road, with an average of 3.64 parking tickets issued per space. When the model was applied to this corridor, it yielded an average predicted value of 3.375 tickets per space, underestimating the actual average by 0.268.

The model's predictive performance was further assessed using the Mean Absolute Error (MAE) and Root Mean Square Error (RMSE), which were 0.94 and 1.26, respectively. These values suggest a slight underestimation of parking demand based on land use patterns. One potential explanation for this discrepancy is the model's use of the number of property addresses to represent commercial land use—a decision driven by the limited availability of detailed floor area data. While this method facilitates broader data acquisition, it may not fully capture the intensity of parking demand generated by large-scale commercial establishments. Future research may enhance model accuracy by incorporating floor area data, differentiated by commercial types.

The findings underscore the need for planners to reconsider existing development control mechanisms and adopt stricter requirements for on-site parking provision, especially in high-demand areas. Additionally, the results highlight the importance of evaluating whether the provision of on-street parking remains appropriate in each context, or whether such spaces should be reallocated for other urban functions (e.g., wider sidewalks or transit lanes). For zones with persistently high parking pressure, policy instruments such as dynamic pricing or stricter time restrictions may be

necessary to manage private vehicle use more effectively.

While the study is based on a single corridor, the analytical framework offers potential applicability to other urban areas with similar data availability. Cities can adopt this model to assess the spatial impacts of land use decisions on parking demand and to develop context-specific parking management strategies.

5. CONCLUSION

This study models on-street parking fee collection as a probabilistic process following a binomial distribution, assuming that land use has a significant impact on on-street parking availability. Through an empirical analysis using the Markov Chain Monte Carlo (MCMC) method, the results indicate that factors such as educational and institutional facilities, medical institutions, commercial and residential land use, as well as off-street parking supply, significantly influence on-street parking demand.

5.1 Conclusion

Based on the findings of this study, the following conclusions are proposed for future policy management of on-street parking and land use in urban areas.

This study focuses on examining the spatial association between surrounding land use and the observed utilization of on-street parking spaces, based on an empirical dataset compiled by the local government using records from parking enforcement operations. Rather than modeling individual travel behavior or origin-destination (OD) flows, the analysis aims to capture how various land use types—particularly those associated with trip-generating activities—relate to localized parking demand under the current transportation context.

Although OD-based demand estimation and mode choice modeling offer valuable behavioral insights, such data were not available within the scope of this study. Instead, land use categories such as commercial areas and institutional facilities were employed as proxies for aggregated travel demand, based on established correlations in prior research.

The binomial distribution model achieves convergence during parameter calibration, indicating its feasibility in predicting the relationship between land use and parking demand. However, the overall model's Deviance Information Criterion (DIC) value is 30,601, suggesting that its goodness-of-fit could be improved. Future research may consider adopting alternative probabilistic distribution models or refining the regression model for land use.

Land use varies across countries due to differences in culture and urban structure. Within the study area, the shortage of parking spaces at educational and institutional facilities has led to spillover effects, whereas medical institutions, having provided sufficient parking facilities, have reduced their reliance on on-street parking—differing from patterns observed in other countries. In contrast, commercial land use consistently contributes to parking challenges in metropolitan areas worldwide. Therefore, strict regulations on auxiliary parking spaces for commercial land use are necessary. For instance, land-use regulations may require doubling the designated parking area or reducing building coverage to increase parking supply.

In recent years, policies aimed at providing sufficient parking spaces in residential areas to meet household demand have shown effectiveness. The demand for on-street parking in residential land use has declined, indicating that land-use regulations requiring the provision of auxiliary parking spaces can effectively internalize parking demand. For example, educational and institutional facilities can incorporate underground parking to accommodate their internal needs while also offering public access, thereby alleviating parking pressure in urban areas. Public transportation service levels were included in the model to explore their potential impact; however, findings indicate that, in Tainan City, public transportation currently exerts limited influence on reducing private vehicle usage due to system limitations and low perceived convenience.

Off-street parking facilities are intended to reduce reliance on on-street parking. However, for users, convenience and pricing remain key factors. Therefore, to encourage the shift toward off-street parking, strategies such as differentiated pricing, time-limited parking, and increased charging frequency can be considered.

To further validate the model's applicability, it was tested on independent data from Minsheng Road, showing reasonable predictive performance. MCMC diagnostics confirmed reliable convergence of parameter estimates. Although spatial heterogeneity and autocorrelation were not explicitly modeled, future studies should address these aspects to improve accuracy. Effective parking management policies, such as dynamic pricing and stricter on-site parking requirements, are recommended based on the findings.

5.2 Future Studies

Based on the technical and data limitations of this study, several recommendations are proposed for future research on the relationship between on-street parking demand and land use.

This approach provides a practical framework for linking land development with parking demand patterns using available empirical data. Future studies may further

enrich this analysis by incorporating OD data derived from household travel surveys, telecom signaling, or GPS-based mobility datasets.

In terms of land-use classification, although address-based categorization can effectively identify actual land-use types, variations in the scale of commercial properties may still impact parking demand. For example, convenience stores, wholesale retailers, and department stores exhibit different parking demand characteristics. Additionally, Taiwan's unique night market commercial activities differ from general commercial land use. Therefore, future research could further explore how different types of commercial land use influence on-street parking demand.

This study's analysis is based on parking data from a single representative month, March 2023, which may limit the generalizability of the findings across other time periods with different travel demand patterns, such as holiday seasons or special events. While the model effectively captures the typical land use–parking demand relationship during stable periods, it does not account for temporal variability or potential seasonal fluctuations. Future research should incorporate longer-term and multi-period data to validate and enhance the model's robustness, particularly in capturing demand variations under diverse temporal contexts.

Moreover, this study estimates parking demand based on hourly patrol-based ticketing records. However, short-duration parking behaviors may be underrepresented due to patrol intervals, potentially underestimating actual parking turnover. With the growing adoption of smart parking systems in Taiwan, AI-powered license plate recognition can now detect parking events lasting as little as five minutes. Incorporating such high-resolution and real-time data in future research could substantially improve the accuracy of parking demand estimation and better support dynamic parking policy formulation.

The advancement of autonomous vehicle (AV) technology is expected to reshape urban parking demand and spatial patterns. AVs can drop off passengers and relocate to remote or centralized parking facilities, potentially reducing the reliance on on-street parking and encouraging the development of shared or automated parking structures. Future studies should employ simulation modeling and scenario analysis to assess the effects of varying AV adoption rates on parking demand and distribution. Behavioral surveys could help evaluate shifts in user preferences under AV-enabled conditions. Additionally, long-term implications for land use planning and curbside management should be addressed to inform adaptive policy responses. To prepare for these changes, policymakers should consider integrating dynamic pricing, demand-responsive allocation, and intelligent transportation systems (ITS), while future studies may incorporate key variables such as parking distance, parking duration costs, and user tolerance thresholds to evaluate parking system performance under AV scenarios.

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