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Original Paper

Temporal-spatial Patterns and Mechanisms of Illegal Street Vending from the Social Sensing Perspective: A Comparison between Law-enforcement-reported and Resident-complained Events

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Abstract

Street vendors play a crucial role in the urban informal economy, particularly in rapidly urbanizing third-world nations. Their presence provides employment, alleviates social pressures, and complements formal commerce. However, regulatory loopholes related to safety and hygiene, along with potential hazards such as traffic congestion, create conflicts between urban governance entities and street vendors. The informal economy's significance to urban landscapes makes integrating street vendors while minimizing conflicts a key issue in urban planning. Limited data has hindered effective solutions for disorder in urban informal spaces. This study addresses this gap by examining the temporal-spatial distribution and underlying mechanisms of unauthorized street vending in Beijing's Fengtai District in 2022. Using records of street vending infractions from municipal enforcement agencies and complaints from residents via the "12345" platform, this research employs statistical methods and machine learning models to analyze disparities in the perception of street vending activities between urban managers and residents. The findings enhance theoretical understanding and offer a bottom-up approach for governance practices, contributing to more humane and sustainable urban planning and governance.

Keywords

street vending, law enforcement, resident complaint, social perception

1. Introduction

1.1 Research Background

1.1.1 Social Context: The COVID-19 Pandemic and the Re-emergence of Informal Economy

Street vendors, as a part of the urban informal economy, have long played an indispensable role worldwide. In China, references to street vending can be traced back to pre-Christian era times, with detailed depictions of merchants and vendors in ancient texts like Zhou Li from the Spring and Autumn period. Internationally, a typical case of street vending is depicted by American sociologist Mitchell Duneier in his studies of New York's street booksellers. Although seemingly insignificant, these vendors have consistently contributed to the maintenance of public order and vibrancy in urban environments.

In the context of economic globalization and rapid urbanization, the presence of street vendors has not diminished; rather, it has become a significant feature of street landscapes in both developed and developing countries, showing an increasingly diversified trend. The International Labour Organization and researchers of the informal economy have continuously focused on this group, arguing that they are not remnants of traditional economies but rather integral parts of modern urban life. Street vendors perform specific social and economic functions, particularly in developing countries, where they constitute a substantial portion of the informal economy and play a critical role in alleviating urban employment pressures.

In China, despite being almost eradicated due to strict crackdowns, street vendors have re-emerged resiliently in the wake of marketization and urbanization post-reform and opening up, becoming a vibrant and widespread presence in urban spaces. This resurgence can be attributed to two major reforms since the 1990s—state-owned enterprise reforms and the diminishing urban-rural divide—which channeled a significant number of laid-off workers and migrant farmers into urban areas. Even between 2016 and 2020, the urbanization rate of the registered population in China continued to grow by an average of one percentage point annually, indicating that over 13 million farmers were migrating to cities and settling as urban residents each year. Due to a lack of education and work experience, many of these migrants found it difficult to integrate into the mainstream urban job market, making street vending a vital reemployment option for many.

However, because street vending often emerges spontaneously from grassroots initiatives, it poses significant challenges for management. The term "street vendor" is often associated with stereotypes of traffic congestion and urban disorder and is seen as a typical element of the informal economy, frequently at odds with urban management authorities. Urban management often resorts to coercive measures to deal with the illegal activities of street vendors, but such approaches can trigger severe social conflicts and have been widely criticized. Amidst the severe economic impact of the COVID-19 pandemic, the role and significance of street vendors have once again drawn attention. According to

data from the National Bureau of Statistics, China's GDP in the first quarter of 2020 decreased by 6.8% year-on-year, while the informal economy accounted for 33% of urban GDP and generated 15% of the overall GDP, providing crucial support for the swift recovery of the economic environment.

After the pandemic, to stimulate economic recovery and job growth and enhance resilience to emergencies, some cities began to issue formal policies encouraging and supporting street vendors. Some of these policies involved the establishment of legal vending zones, thereby reducing the need for vendors to constantly move around, which effectively legalized parts of this economic activity. However, whether such measures, while improving management efficiency and urban aesthetics, might also undermine the inherent vitality and functionality of street vending remains debatable. Other cities attempted more personalized and diversified management models, but existing practical experiences and academic research have not yet provided sufficient support for the development of an ideal governance framework.

1.1.2 Theoretical Context: The Debate Between Digital Governance and Human-Centered Care

As a highly complex, self-evolving system, the city exhibits significant self-organizing characteristics. However, traditional theories of "planning control" and "planning determinism" tend to emphasize a static balance and order, often centered around state-led approaches that overlook urban diversity. This has resulted in persistent gaps between governance concepts and goals, governance boundaries and responsibilities, and governance technologies and values. Today, traditional top-down urban planning concepts can no longer meet the ever-growing material and cultural needs of the people. Instead, open, non-equilibrium, and non-linear planning has once again become the focus and consensus in urban research.

In recent years, with more than half of the global population now living in urban areas, cities have replaced rural areas as the primary living environment for most people, bringing about more complex governance challenges. Coupled with the rapid development and maturity of digital governance tools during the pandemic, such as health codes and travel codes, smart cities have become the dominant paradigm in contemporary urban governance. According to Deloitte's "Super Smart City" report, there are currently over 1,000 smart cities under construction or planning globally, with more than 500 in China alone.

In traditional thinking, "digital governance" is often seen as being at odds with "human-centered care": the former is purpose-driven, emphasizing efficiency and innovation, while the latter focuses more on the subjectivity of individuals, prioritizing citizens' needs and participation. Scholars like Giorgio Agamben have critiqued the expansion of managerial power in digital governance, terming it the "normalization of the state of exception." Building on this, Byung-Chul Han, drawing from Foucault's concept of the "panopticon", critiqued the phenomenon of the "digital panopticon" in contemporary society, highlighting the erosion of individual freedoms.

Based on these critiques, it can be inferred that traditional digital governance often overlooks the social systems and human subjectivity behind street vending, making it difficult to fully understand and address the underlying issues. Therefore, human-centered approaches, which emphasize citizens' needs and participation, may hold more advantages in the governance of street vendors. However, without the support of digital governance, such approaches may still face challenges, such as delays in problem-solving and a lack of unified planning. To achieve efficient and orderly governance, it might be necessary to integrate both digital and human-centered approaches, leveraging the strengths of digital technology to quickly and accurately perceive and analyze citizens' needs, and using these insights as a basis for governance. This integrated approach could help build a governance system that combines intelligence with humanity, supporting the growing demands of urban development while maintaining fairness and justice in the allocation of spatial resources. This is the core concept behind the "human-sensing + object-sensing" smart governance model proposed by scholars like Meng Tianguang and Yan Yu, which aims to efficiently perceive and respond to citizens' needs, analyzing both the objective physical space of the city and the subjective social space of its residents. By strictly adhering to privacy safeguards and conducting technical democracy experiments over time, the widespread digital fears currently prevalent could eventually be allayed.

1.1.3 Disciplinary Context: Patchwork Renewal and Paradigm Shift in Urban Planning

Since the reform and opening-up, China's urbanization process has been characterized by both rapid expansion of urban areas and a paradigm shift in urban planning. Early urban planning primarily focused on incremental growth, emphasizing the development of new areas, which inevitably led to the neglect of arable land and ecological boundaries. In the current pursuit of sustainable development, the dominant disciplinary paradigm in urban planning is shifting from mere incremental planning to more nuanced patchwork renewal, transitioning from outward expansion to inward-focused renewal. This shift implies greater emphasis on in-depth studies of built-up areas, moving away from rigid, long-term blueprints towards more flexible, policy-guided, and detail-oriented approaches that better meet residents' daily needs, making planning increasingly human-centered and refined.

In this process of planning paradigm transformation, street vendors, as significant users of public space resources in cities and as ancient participants in trading activities rich in local culture, should be considered with greater caution and sophistication in planning and management strategies. From another perspective, conducting more detailed and in-depth research on informal economic activities in urban spaces, and continuously building an evidence-based experience system throughout the research process, will contribute to advancing the disciplinary paradigm of urban planning and the ongoing urban renewal movement towards greater specialization.

1.2 Related Concepts

1.2.1 Street Vendors

Street vending refers to the spatial manifestation of the informal economy, specifically indicating temporary business spaces that provide retail services in urban public spaces, commonly found on streets, squares, and similar locations. Those who operate these vending stalls are often referred to as vendors, hawkers, or stall owners, sometimes derogatorily called "ghost vendors" or other terms with negative connotations. The term "street vending" is neutral in itself, signifying not only a business tool but also a mode of utilizing urban public space. Street vending is widespread, occurring spontaneously and randomly, and can be found in a variety of spaces such as streets, alleys, old residential areas, and even underground passages.

This study focuses on "street vendors" specifically in urban street spaces, referring to vendors without fixed business locations. The research examines "illegal street vending activities" as perceived by urban management and residents. These activities are highly public and social, making them easier to observe and statistically analyze. The "urban street space" in this context not only includes the narrow definition of areas within road redlines but also encompasses urban public spaces and residential areas within building redlines. Due to the difficulty of researching indoor vending stalls in enclosed residential areas or on private property, and their limited scope of service, this study does not address these aspects.

1.2.2 Social Perception

In China, social perception data can currently be obtained through two main channels, each with its observational methods. The first dataset is derived from a "top-down" perspective. Supported by digital governance technology, most cities have established grid-based smart city governance systems. These systems integrate infrastructure perception data, including surveillance video, and collect data on various urban events (including street vending) through manual uploads by urban management personnel and voluntary reports from community volunteers. This unified smart city governance system aggregates a large volume of multi-dimensional data into a database for upper-level management's unified review and action. This study refers to this type of data collection as "social perception" to reflect its observational nature from a top-down perspective, even though these data systems lack automated retrieval or processing capabilities.

The second dataset comes from a "bottom-up" perspective, primarily based on the smart governance terminal's information network, as well as the information flow of relevant street vendor activities generated on urban social platforms. It includes various types of media information data, such as official media, digital media, public social media platforms, and various public opinion websites. These data, generally used by digital governance authorities to detect and analyze abnormal social emotions and events through algorithmic processing of online sentiment data, also play a role in public

governance as indirect observation data for assessing public opinions. This study refers to this type of data collection as “bottom-up social perception”.

1.2.3 Smart Urban Management

China’s urban management has followed a unique developmental path, distinct from the “urban management” or “urban administrative law enforcement” practices common in developed countries. The urban management bureau has evolved from grassroots police forces and urban administrative law enforcement teams, continuously absorbing similar departments and expanding its functions and powers, ultimately evolving into an administrative unit capable of governing a wide range of urban public space issues.

Since 2020, digital governance tools such as smart city platforms have gained significant traction. A comprehensive, multi-dimensional urban governance model has been established by integrating technological, social, and administrative systems into a single smart governance system, encompassing major components such as urban big data, urban governance decision-making, and public service systems. This model aims to enhance the city’s integrated perception and analysis capabilities, enabling rapid response to urban governance demands.

Smart urban management is a product of technological advancements, reshaping the traditional model of urban management. It places high demands on digital governance capabilities and the ability to coordinate technology and social systems, while also requiring consideration of the operational logic of the human-social system to avoid becoming a cold “technology giant”.

1.3 Research Objectives

This study investigates the use of social perception data in digital governance to analyze and compare different smart management models for street vendors in urban street spaces. By evaluating management efficiency, user satisfaction, and urban vitality under these models, the study aims to explore the relationship between management models and the street economy, as well as the interaction between digital governance and human-centered approaches. The goal is to provide theoretical insights and practical references for the construction of a new paradigm in urban street space governance that balances efficiency and humanity.

1.4 Research Questions

How does the integration of social perception data into digital governance affect the management of street vendors in urban street spaces? What are the differences in management efficiency, user satisfaction, and urban vitality between different smart management models for street vendors? How can urban governance models be optimized to balance the objectives of order, efficiency, and vitality while addressing the needs of street vendors and other urban stakeholders? What are the implications of integrating digital governance with human-centered care in the context of managing street vendors in urban spaces? How can the insights from this study contribute to the broader discourse on urban

planning and governance in rapidly urbanizing contexts like China?

1.5 Significance of the Study

This research contributes to the field of urban planning and governance by bridging the gap between digital governance tools and human-centered approaches in the context of managing informal economies like street vending. It provides a comprehensive analysis of how social perception data can be leveraged to create more responsive and inclusive urban management models. Additionally, the study's findings have practical implications for policymakers and urban planners seeking to enhance urban vitality while maintaining order and efficiency in public spaces.

2. Method

2.1 Scope of Research and Data

2.1.1 Research Scope

This study selects the urban area of Fengtai District, Beijing, China (Figure 1), as the research scope, for the following reasons:

Firstly, as the capital of China, Beijing plays a leading and exemplary role in economic, cultural, and political spheres across the entire country. This means that, compared to all other cities in China, Beijing must take the lead in experimenting with human-centered transformations in urban governance systems. This is not only because residents with higher living standards require more civilized and efficient urban governance practices, but also because Beijing possesses the essential qualities to serve as a representative case study that can be referenced on a larger scale.

Secondly, Fengtai District plays a crucial role in serving the national and capital strategic framework. Its positioning includes being a model urban area for high-quality, livable living in the capital, and a new business district of the capital with international advanced standards, making it a truly "golden corner" of Beijing. Therefore, if Beijing can serve as a demonstration city for governance models nationwide, Fengtai can likewise serve as a demonstration area for Beijing.

Lastly, Fengtai District has a relatively well-established smart city infrastructure system, capable of providing the two types of social perception data needed for this study, specifically regarding street vendors. These data are currently only accessible in a few cities across the country, including Beijing, Ningbo, and Sanya. Among the districts under Beijing's jurisdiction, Fengtai's social perception data holds significant advantages in terms of both quantity and completeness, making it a suitable foundation for this study.

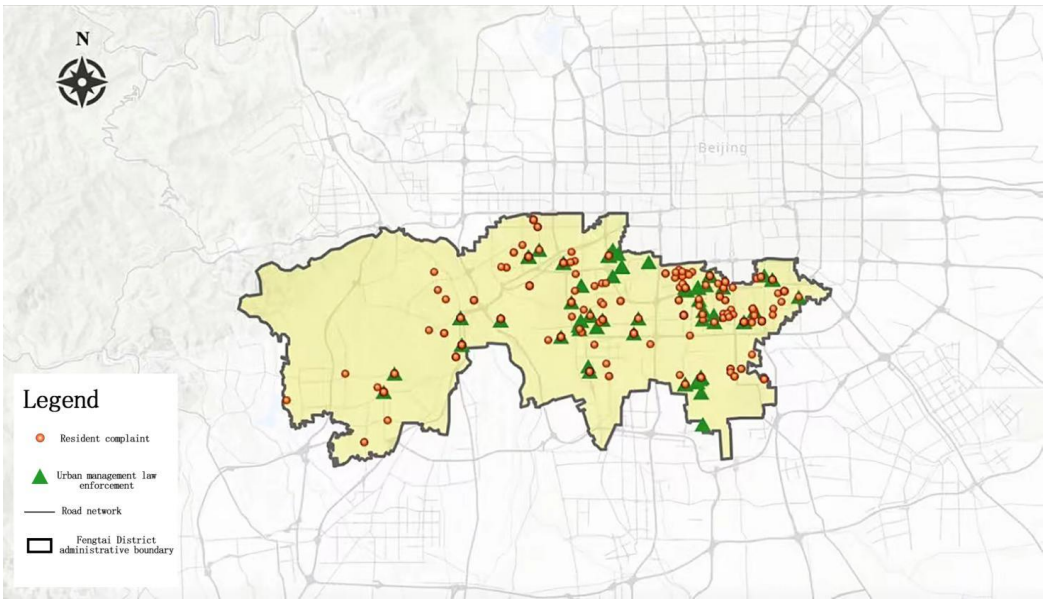


Figure 1. Research Area and Spatial Distribution of Street Vendor Incidents

2.1.2 Research Data

To facilitate subsequent analysis, this study directly defines the specific boundaries of the research area as the administrative boundaries of Fengtai District, Beijing, as delineated by the official authorities. The data on street vendor incidents used in the research come from two sources: (1) The Beijing Smart City Governance Platform, which includes illegal vendor behaviors discovered by grid inspectors in Fengtai District during their patrols (hereinafter referred to as "urban management enforcement" data); (2) The Beijing "12345" hotline, which includes all reports from Fengtai District residents about illegal vendor behaviors that negatively affect public order or private life (hereinafter referred to as "resident complaints" data). During the period from January 1, 2022, to December 31, 2022, a total of 219 reported incidents and 619 complaints with complete spatial and temporal information were geocoded and plotted on a map using ArcGIS, and subsequently used for further analysis. Other types of data include street view facility data from Baidu Maps; Point of Interest (POI) data and road length, land area data from Amap; housing data, such as the number of residential units and housing prices from Anjuke; per capita consumption data from Dianping; population density data from WorldPop; and on-site survey data, including the number of entrances, road width, and sidewalk width. To protect privacy, all data were strictly anonymized and a confidentiality agreement was signed before use, limiting the data to this undergraduate research project.

2.2 Research Methods and Framework

2.2.1 Research Methods

Firstly, all cleaned data were geocoded and imported into ArcGIS Online to observe their general distribution. For statistical convenience, the research area was divided into secondary grids of 600 m × 600 m, and the number of incidents within each grid was recalculated. Considering the working hours of urban management personnel, we further divided the incidents into work hours (weekdays 8:00-17:00) and non-work hours (weekdays 0:00-7:00, 18:00-24:00, weekends, and public holidays), and counted the number of incidents within each grid for both periods. This laid the foundation for the subsequent spatial-temporal analysis of the two types of street vendor incidents.

Next, we established 300 m radius buffers for all illegal street vendor incidents and used overlay analysis to derive the intersections and symmetric differences between resident complaints and urban management enforcement incidents. By calculating the geographical spatial variables of each overlay unit, we extracted the zonal spatial characteristics of the two types of incidents (including specific and common types of incidents). The data from the buffer intersections represent the overlapping areas of the two types of illegal street vendor behavior in space, providing shared spatial characteristics that help in understanding their relationship and mutual influence. Symmetric difference represents the difference or conflict in zonal spatial characteristics between the two types of illegal street vendor behavior. Here, POI data were used as indicators of different regional spatial characteristics, as they reflect the semantic functions of urban space, which in turn can serve as explanatory factors for the occurrence of street vendor incidents.

Subsequently, using the grid as the basic analytical unit, we took the number of street vendor incidents that encountered resident complaints and urban management enforcement within each grid as the dependent variable. The independent variables include two major categories: socio-economic factors and built environment factors, with their respective data sources and the calculation methods of certain factors summarized in the table above. Regarding model selection, we first used simple regression methods to analyze the spatial-temporal mechanisms of street vendor incidents. Given that the number of street vendor incidents within each grid is a natural number greater than or equal to 0, and a significant portion of the values is 0, we considered using the Tobit model in further analysis, which is a regression model suitable for handling truncated or right-skewed continuous dependent variables. The formula (Figure 2) for the Tobit model is as follows:

$$y_i^* = X_i\beta + e_i$$

$$y_i = \begin{cases} y_i^*, y_i^* > 0 \\ 0, y_i^* \leq 0 \end{cases}$$

Figure 2. Formula of Tobit Model

Where yi is the observed dependent variable, yi is the latent dependent variable, xi is the independent variable, β is the model parameter, and i is the error term. The Tobit model estimates the model parameters through maximum likelihood estimation or other fitting methods, and considering the truncation of the dependent variable, its prediction results will be more accurate and easier to interpret.

Finally, machine learning methods were applied to validate the regression results. As an emerging research method, machine learning has been widely used in existing studies on street vendors to automatically monitor street vendor activities and predict their specific movement paths. In this study, machine learning will be used as a powerful predictive tool for further analysis of the spatial-temporal mechanisms of street vendors. Considering that the data scale within Fengtai District is relatively small compared to the requirements of deep neural network methods, and the specific research objectives of this study, we consider using SVM (Support Vector Machine) and XGBoost methods to cross-validate the results inferred from the Tobit model. SVM is a supervised learning algorithm used for classification and regression tasks, and its basic idea is to find an optimal hyperplane to separate data points of different categories, maximizing the margin between two classes. In classification tasks, SVM aims to find a decision boundary that best separates the data points, while in regression tasks, it seeks to fit the data with a line or curve that best represents the data. XGBoost is an ensemble learning algorithm based on decision trees, used for solving classification and regression problems. It is an implementation of Gradient Boosting Tree, which gradually improves model performance by training multiple decision trees. XGBoost builds decision trees by minimizing the loss function and optimizes model parameters using the gradient descent method. Compared to traditional gradient boosting trees, XGBoost introduces a regularization term, improving the model's generalization ability, and has advancements in both training speed and accuracy. Most parameters are set to default values, except for "gamma" and "kernel" in SVM and "max_depth" and "eta" in XGBoost. Repeated experiments are conducted to select the parameter values with the most accurate results. 75% of the data is used for training the model, and the remaining data is used as the test set to calculate the model's error rate.

Additionally, the XGBoost model reports the "importance" of each independent variable. Here, the average gain of all splits is selected as the measure of variable importance, to rank the explanatory contribution of each variable in the model.

3. Tests

3.1 Spatiotemporal Distribution Patterns of Two Types of Illegal Street Vendor Activities

Grid analysis reveals significant differences in both the total number and spatiotemporal distribution patterns of illegal street vendor activities reported through the two channels of urban management enforcement and resident complaints (Figure 3). Notably, the number of incidents reported by residents far exceeds those reported by urban management, particularly during non-working hours. The ratio of incidents reported during working versus non-working hours also differs between the two. Specifically, urban management reported 86 incidents during working hours, accounting for 62.32%, while only 52 incidents were reported during non-working hours, accounting for 37.68%. In contrast, residents lodged 294 complaints during working hours, representing 47.5%, and 325 complaints during non-working hours, surpassing half of the total at 52.5%. The disparity in total numbers reflects the current inadequacies in urban management's intervention in social issues, particularly during non-working hours when patrol strength is reduced, limiting the ability to promptly detect and address problems. During these hours, residents are more sensitive to the negative externalities of street vendors, yet effective intervention from management often only occurs after normal life has already been disrupted.

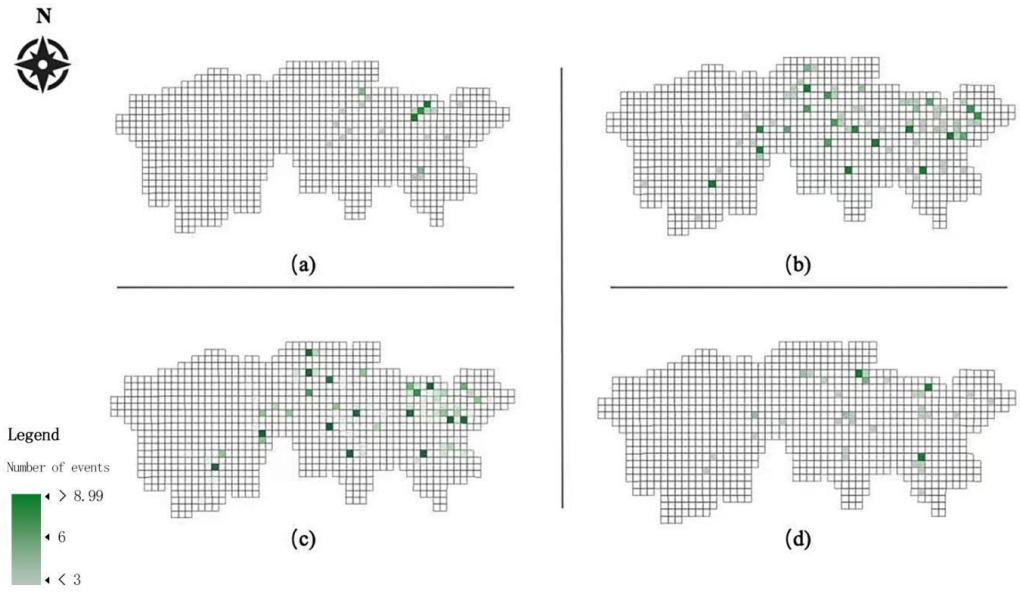


Figure 3. Spatiotemporal Distribution of Street Vendor Incidents under Two Perceptions

(a) Incidents reported by urban management during non-working hours; (b) Incidents reported by residents during working hours; (c) Incidents reported by residents during non-working hours; (d) Incidents reported by urban management during working hours

From a spatial perspective, incidents reported through both channels at different times are concentrated in the northeastern side of Fengtai District, radiating southwest. During working hours, incidents reported by urban management are primarily concentrated around Lize Bridge and Caihuying Bridge, both of which are significant traffic hubs in Fengtai District, with dense flows of people and vehicles. Another hotspot is the Xinfadi area, one of the largest agricultural wholesale markets in North China and a hub for long-distance passenger transport, where the flow of people is also exceedingly high. Incidents reported by urban management during non-working hours are relatively sparse, with a concentrated distribution in several communities in Xiluoyuan, while other areas have only scattered reports, with virtually none on the western side. In comparison, the locations of resident complaints are much more dispersed, with little variation between non-working and working hours. These complaints are primarily concentrated around places such as Aeon Mall, Nanyuan Forest Wetland Park, Fengtai Science Park, as well as residential areas near Zhangyi Village Road and Dongshanpo, closely aligning with the daily living spaces of city residents.

Overall, the spatiotemporal patterns of street vendor activities under the two perceptions show significant differences. Areas of focus for urban management are mostly concentrated in dense population spaces such as traffic hubs and wholesale markets during working hours, with fewer incidents showing a clear concentration trend. On the other hand, areas with concentrated resident complaints are more numerous, primarily including residential areas, shopping centers, parks, and office parks, which are common everyday living spaces. Incident numbers reported during non-working hours slightly exceed those during working hours, with a further concentration trend towards residential areas.

3.2 Comparative Analysis of Zonal Spatial Characteristics of Two Types of Illegal Street Vendor Activities

By employing buffer and overlay analysis methods in ArcGIS, the study identifies similarities and differences in the zonal spatial characteristics of illegal street vendor activities perceived under the two channels. Here, “urban management enforcement” and “resident complaints” (all characteristics) refer to the POI (Point of Interest) structure of non-overlapping events from both channels, with their intersection representing the buffer zone overlap. The POI structure of this overlap reflects the common regional characteristics of both types of events. As observed in the figure below (Figure 4), the proportion of dining venues within the overlap zone is significantly higher than other categories, reaching 32%, which aligns with the primary type of street vendor activities studied (snack and food

supply). This is partly due to the sheer number of dining venues in Fengtai District, and partly supports the fact that as an informal economy, street vendors often coexist with formal businesses of similar nature, sharing locations, customers, and services. The next most common type of venue is shopping locations, though interestingly, within the buffer zone of urban management-reported incidents, shopping venues account for 30%, while in the buffer zone of resident-reported incidents, this figure is only 23%. One reason for this is that shopping areas, often crowded with people and characterized by large, disordered spaces, serve as prime spots for street vendors and also as hotspots for illegal and nuisance activities, making enforcement in these areas more effective for "precision strikes". Additionally, the bustling, busy, and noisy nature of shopping venues, which symbolize urban "vitality", typically deters interference unless they disrupt nearby residents' work or rest. Other significant types of venues include leisure venues and parking lots, which also attract vendors due to their high foot traffic and ample open spaces. Residential and municipal venues follow, with residential venues more prevalent in the buffer zones of resident complaints, while municipal venues are more common in urban management-reported incidents, further highlighting the zonal spatial characteristic differences under the two perspectives. Lastly, financial and medical venues are noted, with medical venues accounting for 7% in the buffer zones of resident complaints, possibly linked to patients' higher environmental standards.

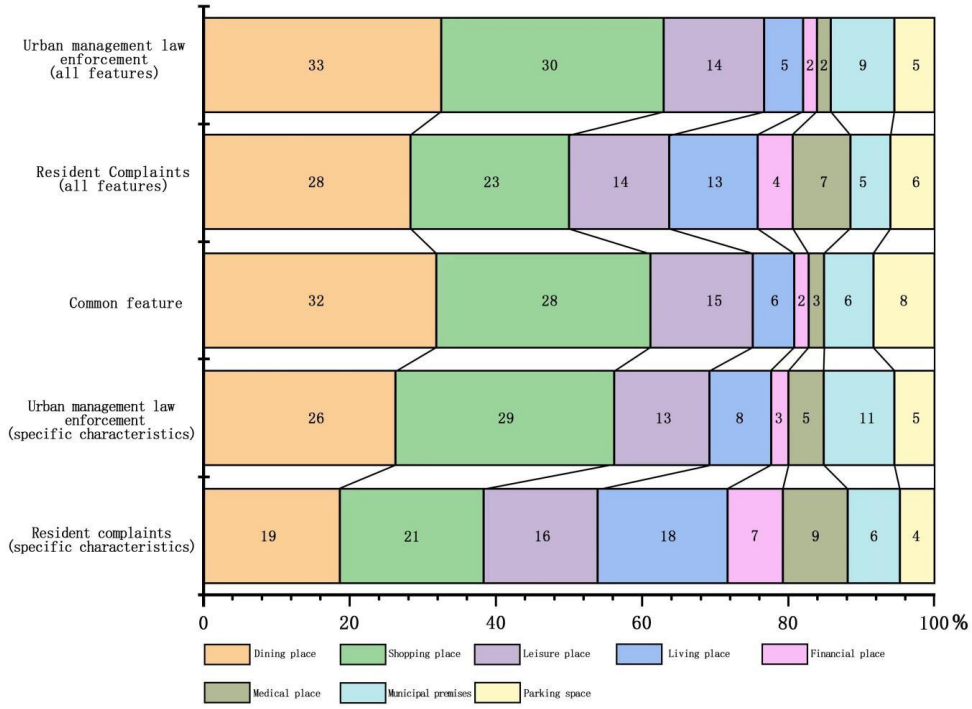


Figure 4. Comparison of POI Composition within the Buffer Zones of Illegal Street Vendor Activities under Different Perceptions

Additionally, the symmetric difference of buffer zones provides clearer insights into the specific regional characteristics of the two types of incidents. For urban management-reported incidents, shopping venues and dining venues contribute over half of the POI percentage within the buffer zones. This is partly due to the sheer number of such venues and partly suggests potential issues with the breadth of coverage in urban management's enforcement, possibly due to fixed patrol schedules and locations. Municipal and residential venues follow, with the proportion of municipal venues exceeding residential venues by 3%, even though the former are fewer in number, indicating that urban management enforcement may still predominantly operate as a top-down "command-execution" model rather than genuinely adopting a people-centric approach. Correspondingly, in the buffer zones of resident-reported incidents, although dining and shopping venues also contribute significantly to the POI percentage, the distribution of venue types is more balanced overall, particularly with residential venues accounting for nearly one-fifth. Another notable observation is the proportion of financial venues, which reaches 9%, far exceeding that in urban management-specific areas and the shared zones. These venues are often bright and clean in appearance, making it difficult to detect issues without careful observation. However, people working or conducting business in these venues typically have

higher expectations for environmental quality, representing another area where urban management enforcement needs to improve. Overall, despite some differences in specific proportions, these findings align with the overall spatial distribution patterns and form one of the bases for the machine learning model design in the following section.

3.3 Spatiotemporal Mechanisms of Illegal Street Vendor Activities

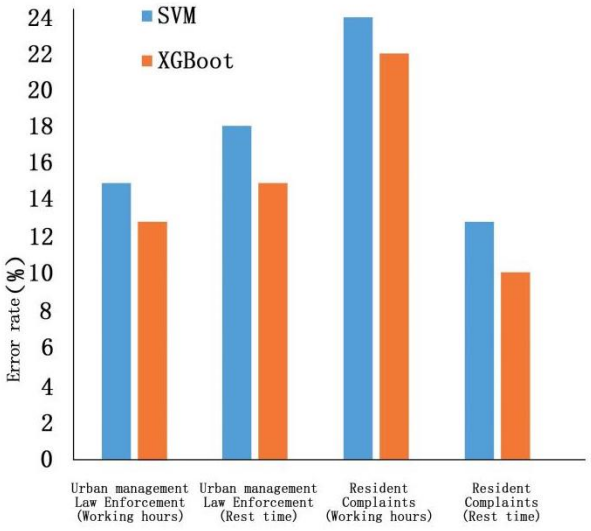
The research results above indicate significant differences in the spatiotemporal distribution and zonal spatial characteristics of illegal street vendor activities reported through urban management enforcement and resident complaints. However, these differences are not without logical patterns. To better elucidate the mechanisms behind each type of incident, Tobit regression analysis was applied to the data from both urban management enforcement and resident complaints, with separate treatment of data during working and non-working hours, resulting in four distinct models. Machine learning methods, including SVM (Support Vector Machine) and XGBoost, were further employed to validate the regression results, leading to the interesting findings presented in the following tables and figures (Figure 5 & Figure 6).

Firstly, there are significant differences in the spatial mechanisms of incidents across different time frames. For urban management-reported incidents, the correlation coefficients of influencing factors during working hours are generally higher than those during non-working hours. This can be interpreted as urban management's patrol routes during working hours having more pronounced tendencies. For instance, population density and road network density show a strong positive correlation with the distribution of street vendor incidents during working hours, consistent with the earlier analysis of the spatiotemporal distribution of this type of street vendor activities. Intersection density, often a composite reflection of population and road network density, similarly shows a strong positive correlation. Although the density of public facilities is not significantly correlated during working hours, it shows a strong positive correlation during non-working hours. In practice, this is easily understood as citizens' nighttime activities often concentrate in parks, squares, and other places dense with public facilities, where street vendors also gather to attract more customers. This suggests that urban management personnel's patrol route selection is at least partially based on empirical self-classification mechanisms. Similar patterns are observed for the density of entrances and the proximity to urban management offices. During non-working hours, various venues, particularly shopping malls, see more street vendor gatherings near their entrances; urban management also tends to prefer patrolling near fixed enforcement points. In contrast, for resident-reported incidents, the number of significant influencing factors during non-working hours is much higher than during working hours. This partly confirms that the intensive enforcement by urban management during working hours has been relatively effective, but it can also be interpreted as residents having higher expectations for quiet during nighttime rest, especially in areas with dense buildings and road networks. Conversely, areas

near urban management offices show a significant negative correlation during non-working hours, likely because they remain under direct surveillance by enforcers during these times. Moreover, sidewalk width is negatively correlated with all four types of incidents, but this relationship is only significant for incidents reported by urban management, suggesting that street vendors tend to gather on narrower paths rather than wide avenues, which residents do not pay much attention to. Even during working hours, although urban management focuses on controlling intersections and densely populated areas, it overlooks vendor activities on pedestrian paths or in quiet corners.

Secondly, the temporal mechanisms of street vendor activities exhibit commonalities across different channels and time frames. The correlation coefficients of population density, road network density, and intersection density are all positive and significant in the models for both working and non-working hours. This suggests that these factors remain influential during both time frames. However, for incidents reported by residents, these factors have a greater influence during non-working hours. This discrepancy may be due to the changes in the spatial utilization of public areas at different times of the day, and residents' perceptions of the disturbances caused by street vendor activities may vary accordingly. Additionally, the density of public facilities and the proximity to urban management offices show a negative correlation during non-working hours, indicating that street vendors are more likely to avoid areas with concentrated public facilities and urban management presence during these times.

Overall, the findings indicate that illegal street vendor activities are influenced by a range of spatiotemporal factors, with distinct differences in the underlying mechanisms between incidents reported through urban management enforcement and those reported by residents. These differences highlight the need for tailored strategies in managing street vendor activities, taking into account the specific spatiotemporal dynamics at play.



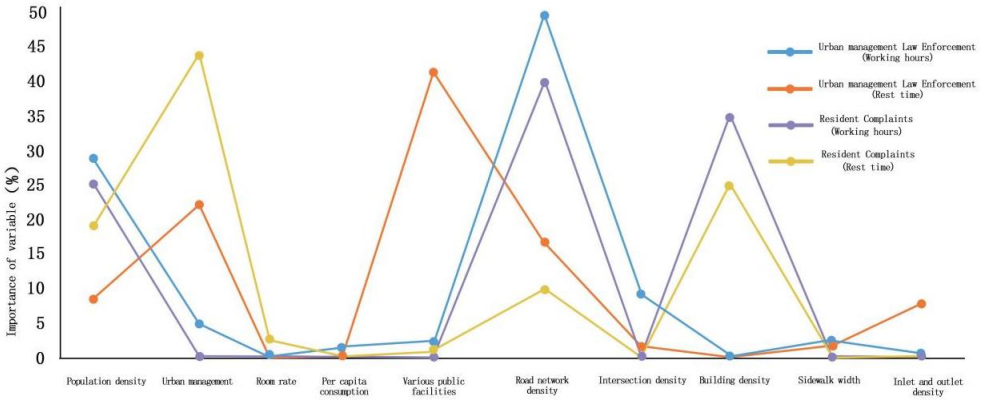


Figure 5 & Figure 6. Comparison of Temporal Mechanisms of Illegal Street Vendor Activities under Different Perceptions

The above results provide a comprehensive understanding of the spatiotemporal mechanisms of illegal street vendor activities, offering valuable insights for urban management strategies. The findings underscore the importance of considering both the spatial and temporal dimensions when formulating policies and interventions to address the challenges posed by street vendor activities.

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