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Examining the Conceptual Model of Potential Urban Development Patch (PUDP), VOCs, and Food Culture in Urban Ecology: A Case in Chengdu, China

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Abstract: In China, traditional food is a significant element of culture that affects human behaviors. The point of interest (POI) of traditional food restaurants' location and their volatile organic compounds (VOCs) emissions affect the urban ecology. Rather than examine potential urban development patch (PUDP) based on land use data, the perspective of this paper is to examine the PUDP, air quality, and food culture in urban ecology in Chengdu, China. Methods: First, the research identifies three types of PUDP models (open PUDP, landscape PUDP, and conflict PUDP) with the weighted overlay of land use data, then uses machine learning to examine the relationship between PUDP, POI of traditional food restaurant, and VOCs. Results: The study generates three types of PUDP which are open PUDP, landscape PUDP, and conflict PUDP. VOCs and POI of traditional restaurant have a strong correlation, and both have a significant negative correlation with open PUDP. However, the landscape PUDP and conflict PUDP do not show an obvious relationship with food POI and VOCs. Conclusion: The results indicate that the future urban ecology should consider restaurant location, VOCs from restaurants, and their relationship to urban land use data as they have a strong relationship.

Keywords: urban food culture; volatile organic compounds (VOCs); point of interest (POI); potential urban development patch (PUDP); urban ecology; China

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1. Introduction and Background

1.1. Overview

Culture is an essential factor in affecting the development of cities and the relevant human activities, which should be regarded as a key factor in urban design. As a general concept, urban culture consists of various aspects, and food is an important one among them, especially in China, a country famous for diverse traditional food. In most Chinese cities, local food serves an indispensable role in citizens' daily lives and has even become a symbol of the city [1]. On the other hand, the food culture and catering industry are some of the virtual drives affecting the form, evolution, renovation, and design of urban space [2]. Therefore, including information related to local food in Chinese urban planning research is necessary.

The food point of interest (POI) explains the data related to food, which can be mapped, analyzed, and calculated geospatially. More than that, the food POI includes the location and type of food POI, and broader data such as price, customer flow, visiting frequency, and reviews. Thus, most scholars use POI and land use data to generate the suitability map of urban green space. However, the POI of traditional restaurant can also reflect the air quality and potentially help the urban ecology. At the same time, although the air pollution issue in cities has received much attention in urban planning research, the air quality problem

related to the catering industry is not often discussed, especially in research on food culture and urban space. As an essential measurement of air quality associated with food, the volatile organic compounds (VOCs) are a fundamental factor in evaluating the catering industry's influence on urban air quality. In recent years, China has paid increasingly more attention to urban ecological construction. As an important factor affecting urban ecology, air quality has also received increasing attention. However, compared with natural spaces, the implementation of ecological construction in urban contexts is more difficult due to the complex social and economic activities. Urban air quality is controlled with various complex factors and ignoring any point could affect the effectiveness of urban air governance. Catering-related VOCs, as one of these factors, has caused serious urban air pollution in China. Therefore, examining the factors of VOCs, food POI, and urban land use research together in Chinese cities may be more appropriate.

In summary, local food is a carrier of urban culture and a strong drive affecting urban ecology and urban design in China, and it may simultaneously threaten urban air quality. This research chose Chengdu as the study site and systematically investigated the food POI, VOCs related to local catering, and new classification of urban land use to examine the relationship among them. This study aimed to explore how to inspire optimal urban planning and design based on the food POI, catering related VOCs, and urban space categorization. The significance of this research is to bring the perspective on exploring new factors and their relationship to urban ecology.

1.2. Existing Classifications of Urban Space

Urban public spaces are areas where urban residents can engage in daily activities and participate in social interactions [3]. Swanwicks [4] classified the external urban environment into green and grey spaces. Green space includes parks, gardens, natural and semi-natural green spaces, allotments, community and city farms, green corridors, and amenity greens. The grey space contains functional grey spaces and civic space. Open space means fields and forests that are purposefully kept undeveloped while the land around them is turned into houses and roads [5]. Based on the function of land use, open spaces are classified into two major categories: providing recreation and other services to society, and conserving natural values [6,7]. According to most existing studies of urban land use, urban green space and grey space are two essential terms. There are various methods to identify and categorize different urban space and landscape use. Using remote sense and unmanned aerial vehicles (UAVs) imagery to detect land cover types and spatial features are widely used ways to identify parameters related to urban space categorization [8]. Those data could be located and analyzed through the geographic information system (GIS) platform, where the suitability mapping could be conducted [9]. Meanwhile, based on the GIS suitability mapping, existing studies have proposed different criteria of weighted overlays to categorize the types of urban space [10].

1.3. Application of Food POI in Urban Development

Food, one of the important cultural symbols in the history of human beings, has an irreplaceable impact on social activities and human behaviors in big cities. Food is considered from a multifunctional standpoint [11]. It is not solely aimed at meeting human needs (health function); it also serves to create and maintain social interactions through the organization of the movement of products (market role) and the organization of meals. Food can be considered an essential part of contributing to the social interactions in every city. It also provides pleasure and, thus, has an artistic aspect, as promoted by gastronomy (hedonic function) [12]. During the COVID-19 pandemic, the actual economy received an unprecedented shock. The food and beverage industry is an integral part of the urban economy that cannot be replaced despite the rapid development of the Internet economy. The food and beverage industry has also become one of the most critical influences on the development of urban planning, one of the critical components of modern urban culture. The concept of "food cities" originated from the 2015 global Creative Cities Network's

"food capitals" competition, in which 18 cities from 15 countries around the world were selected as "food capitals" by the end of 2015 [13].

As China's culinary capital, Chengdu is highly heterogeneous in terms of food culture, with food influencing the behavioral patterns of the city's population and, thus, its development plans. Points of interest (POIs) are places where people gather and conduct daily activities. Understanding POI configurations of various urban regions (e.g., administrative districts, neighborhoods, commercial areas, planning areas, metro station areas, etc.) are beneficial for urban planners [14], investors, advertisers, and citizens. Understanding and investigating POIs related to food are significant to quantifying the data on food in urban areas. Rizvi [15] indicated food point of interests (FPOIs) and proposed a choice model to forecast human behavior. However, limited research has explored the relationship between food POI, restaurant emissions, and urban space. By investigating POI configurations of the regions, urban planners can evaluate their functionalities, vibrancy, and developments [16–19]. The POI of restaurants can represent the food situation and be visualized through a geographic information system on a map. Meituan APP maintained its leading position in the field of restaurant collecting and sharing. According to the 2018 Q3 China Mobile Internet Industry Development Analysis Report released by the third-party Internet big data monitoring agency Trustdata, Meituan, Eleme, and Baidu takeaway accounted for 60.1%, 29.3% and 2.9%, respectively, in the third quarter of 2018 [20]. Meituan APP can provide a large range of food POI data.

1.4. Food POI and Air Quality

Cooking fumes significantly contribute to the pollution issues in the urban environment [21]. However, limited studies have focused on the VOCs in the restaurant and the urban landscape space. Through the research by Huang [22], the most significant mass concentration of VOCs was found in hot pot restaurants. However, few existing studies have focused on the relationship between urban activity space and restaurant pollution [23]. Existing studies relied on traditional urban data, such as roads, land use, and buildings, with little research on food reclassification, evaluation, and co-planning with urban open spaces. Food POI provides a new way of thinking about the development of cities. The number and proportion of urban patches are closely related to the development of urban cuisine.

1.5. Knowledge Gaps PUDP

According to the current literature, there is limited study about the relationship between potential urban development patch and the emissions of polluted air. To fill the gap, POI of traditional restaurants may act as a bridge to connect them. To examine this, the research needs to generate the potential urban development patch (PUDP) with setting the parameters and calculating the VOCs of local traditional restaurants by using their POI data. Based on these two essential parts, this study used machine learning to explore the connection between VOCs (include POI) and PUDP. The results were expected to examine their relationship and to see whether future studies were necessary to consider this in constructing urban ecology in China.

2. Research Methods and Data Analysis

2.1. Theoretical Framework of Research Method

This research chose Chengdu as the study site. It investigated a conceptual model to identify the PUDPs in Chengdu based on the urban area's spatial features and land use. After that, this research also discussed the possible development and optimization directions of PUDPs in Chengdu by studying its relationship to POI of local traditional food restaurants and VOCs. Therefore, a systematic model was established which combined food POI, urban space, and VOCs. This model indicated how they interacted according to the theoretical framework of this research (Figure 1). Firstly, a data-driven method was adopted to obtain food POI data from social media and establish a food–emission measurement

system. Secondly, based on the ArcGIS platform, researchers explored the high-density food hub by using the density calculation and measured the VOCs based on each high-density food hub according to the customer flow and restaurant visiting frequency. Then, this research studied different urban space and defined the concept of a PUDP. This research also proposed the classification criteria with weighted calculation of different space features such as pavement, green coverage, hydrology, etc. Last, a quantitative model and statistical analysis were applied to examine the relationship between food POI, VOCs, and PUDP.

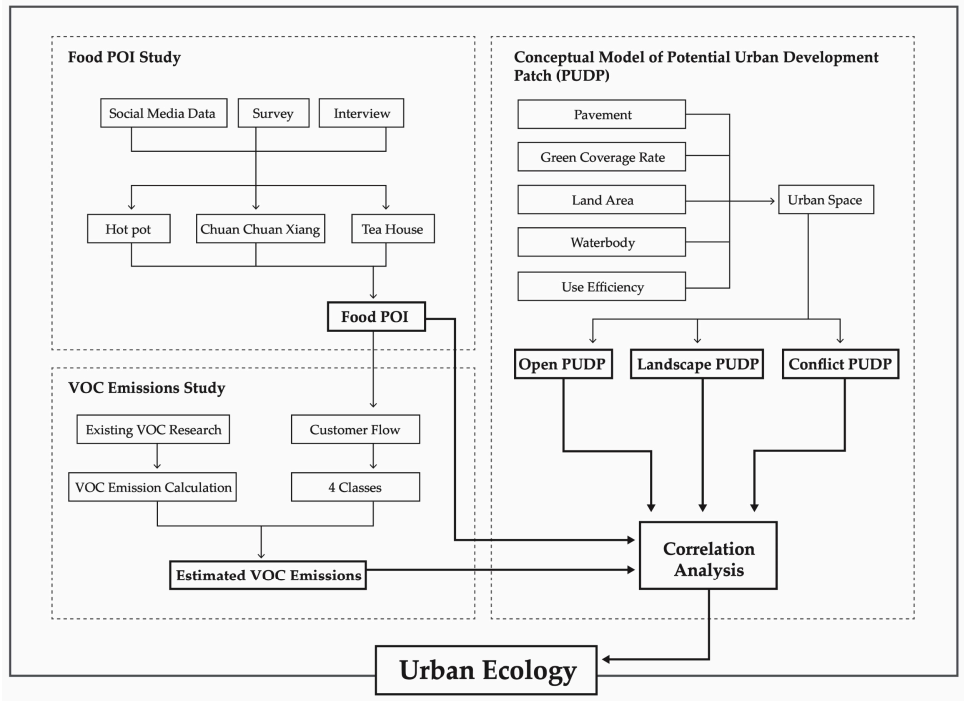

Figure 1. Theoretical concept and framework of the research (source: authors) which explains the core theoretical concept of this research.

2.2. Research Implementation

2.2.1. Samples of the Study Site Based on Food POI

UNESCO awarded Chengdu the title of "City of Gastronomy" in 2010, making it the first city in Asia to enjoy this international honor and a member of the UNESCO Creative Cities Network, which marked a new historical stage in the development of Chengdu's food industry [24]. Chengdu is the cradle and center of Sichuan cuisine, one of the four references of Chinese cuisine: Sichuan cuisine, Guangdong cuisine, Shandong cuisine, and the Yangtze and Huaihe riverside cuisine. Catering is also an important part of Chengdu's service sector. Chengdu, a provincial capital city of Sichuan, is home to 62,509 catering enterprises giving work to 248,500 employees. In 2008, the city accomplished retail sales of nearly USD 44 billion, which ranked fifth across the country and contributed significantly to local employment and economic growth. The city boasts over 60,000 restaurants, more than 2300 renowned chefs, and serving masters [25].

The study site was located in Chengdu's downtown area, with the longest history and culinary traditions. The primary study area included two municipal districts, Jinjiang District and Wuhou District, with a total area of 137.48 square kilometers. In addition, the subject of the study was representative of the traditional cuisine of Chengdu, which was hot pot, Chuan Chuan Xiang (a Chengdu local food that string up ingredients with bamboo sticks and immerses them in spicy oil), and tea.

At the starting stage of this research, researchers interviewed 150 Chengdu local people with designed questionnaires to understand what food was potentially the specific study object. Participants were asked about their preference and frequency of eating a kind of food, according to the report "Composition of Chengdu's main catering industry in

2020 and 2021" from Meituan APP. The results (Figure 2) showed that the local traditional food, including hot pot, Chuan Chuan Xiang, and tea, were preferred and purchased more by participants. Participants also emphasized the cultural value of these foods. Then, focusing on hot pot, Chuan Chuan Xiang, and tea, researchers conducted another round of interviews with more than 100 participants to understand what factors affected people's consumption of these foods. These factors included food taste, price, location, surrounding environment, serving quality, and brand reputation. All the participants were selected randomly in three commercial zones in Jinjiang District and Wuhou District. The gender and age of participants were balanced, and each participant had 5 min to finish the questionnaire. To understand participants' preferences of these factors, the questionnaire was designed with 12 questions. The results showed that people cared more about food taste, serving quality, price, environment, and location. According to the results, the urban space related to food (including the environment and location of a food place) affected people's choice of food.

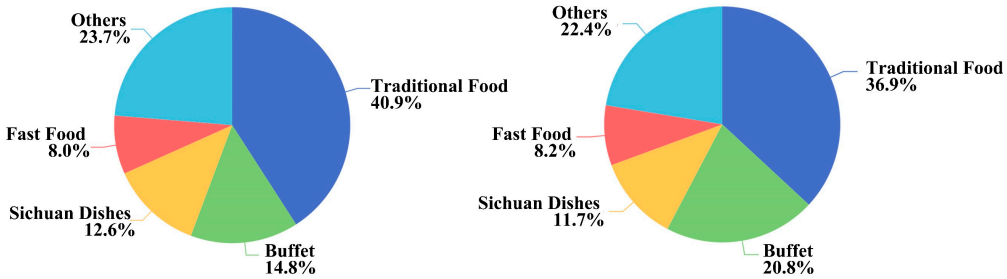

Figure 2. Composition of Chengdu's primary catering industry in 2017 (**left**) and 2018 (**right**) (Data from Meituan APP; source: authors).

Confirming hot pot, Chuan Chuan Xiang, and tea as the primary food representatives in this study, researchers collected POI information related to food from social media. The data source of this research was the 2020 Chengdu catering industry information disclosed by Meituan APP, the most widely used and explored restaurant review app in China. These data included the restaurant's name, primary business type, location and address, the content of customer reviews, average meal price, overall rating score, etc. These data covered 1355 hot pot restaurants, 604 Chuan Chuan Xiang, and 1152 teahouses. Based on those data, this research developed a systematic study on improving urban ecology by involving the POI of food. Wuhou District had a total of 1966 food POIs, and Jinjiang District had 1145 (Table 1).

Table 1. Food categories and data in Jinjiang District and Wuhou District (source: authors).

Variable		Frequency	Percent
Food Type	Chuan Chuan Xiang	604	19.4
	Hot pot	1355	43.6
	Teahouse	1152	37.0
District	Wuhou District	1966	63.2
	Jinjiang District	1145	36.8

To examine the relationship between VOCs and PUDP in the next stage, the research needed to generate multiple samples of study sites via food POI. Thus, the research proposed to identify the high-density food hubs in Jinjiang District and Wuhou District. To obtain this, we used the kernel density tool in ArcGIS based on the POI data of traditional restaurant distribution in the Wuhou and Jinjiang districts. The results showed that 15 high-density food hubs were identified (Figure 3), at the same time, from each food center, an influence range of 1000 m was generated to help the following calculations of PUDP areas and VOCs.

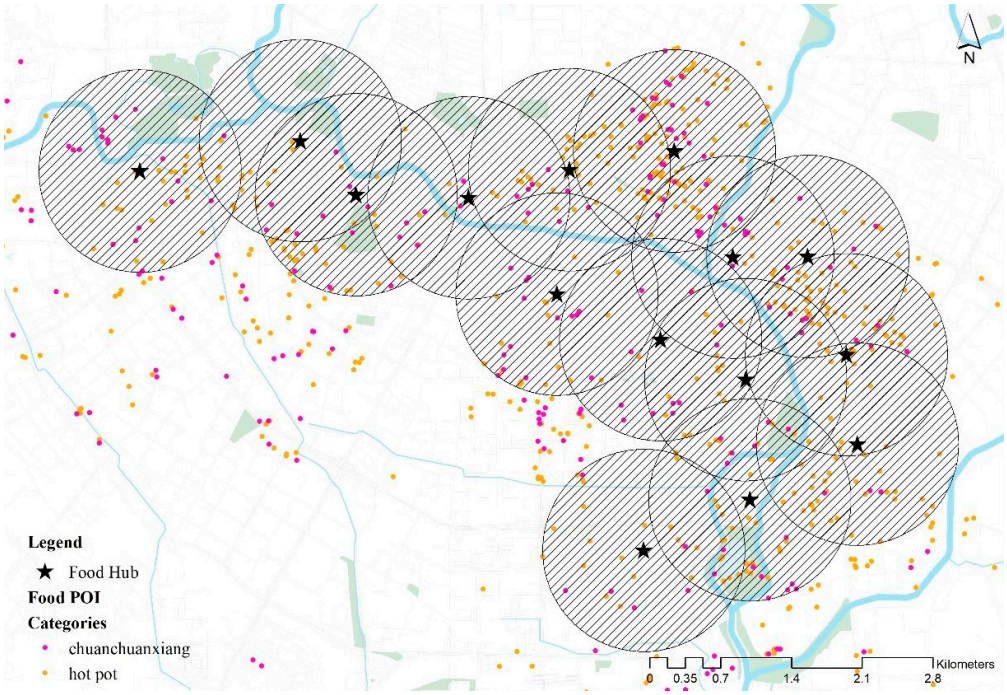

Figure 3. Mapping of the 15 high-density food hubs (source: authors).

2.2.2. VOCs and Air Quality

To calculate the VOC emissions of restaurants in targeted samples zone, the research referred to the research from Wang's team. According to the scale of restaurants, Wang [26] and his team invented the VOC emission factors to estimate the total emissions of VOCs. Emission factors of VOCs related to per person (EF_{person}, g/person), per kitchen stove ($EF_{kitchen\ stove}$, g/h·stove), and per hour (EF_{hour}, g/h) were investigated. Background VOC concentrations for each individual measurement were subtracted prior to performing the calculations. Emission factors for VOCs were calculated according to Equations (1)–(3), respectively:

$$EF_{person} = \frac{\sum_i VOC_i \times F \times 10^6}{P} \quad (1)$$

$$EF_{kitchen\ stove} = \frac{\sum_i VOC_i \times F \times 10^6}{N} \quad (2)$$

$$EF_{hour} = \sum_i VOC_i \times F \times 10^6 \quad (3)$$

where VOC_i is the mass concentration of species i, μg/m^3, F is the flow rate, m^3/h, P is the hourly number of customers, person/h, and N is the number of kitchen stoves in each restaurant. As the research chose hot pot, Chuan Chuan Xiang, and tea as the three study samples, and tea house almost contributed no VOC emissions to the total VOC emissions, only hot pot and Chuan Chuan Xiang were discussed in terms of VOCs. According to the national Municipal Food and Drug Administration, restaurants could be classified into four categories, extra-large, large, medium, or small scales, based on the amount of area occupied and the number of seats [27]. By following these, all the restaurants in the study site were divided into four classes (Figures 4 and 5).

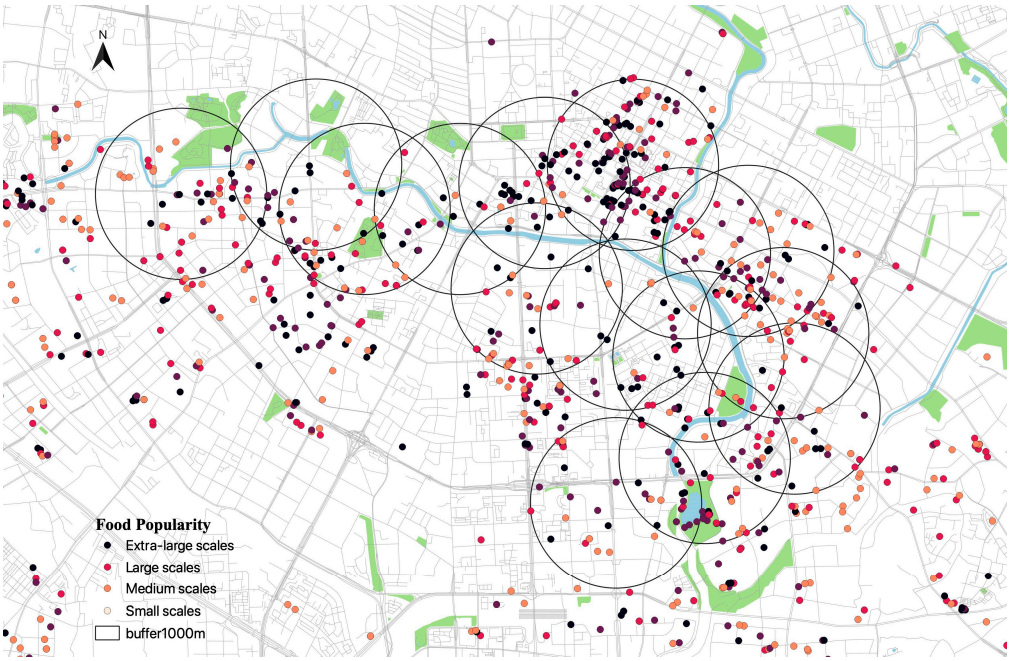

Figure 4. Mapping of the four restaurant categories (source: authors).

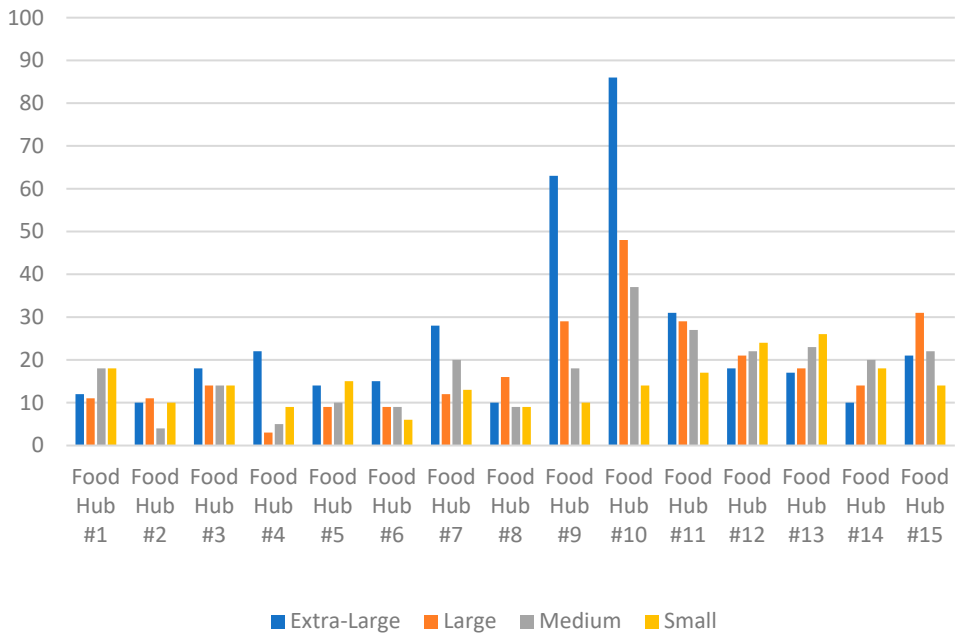

Figure 5. Distribution of restaurants' categories in each food hub (source: authors).

According to Wang et al.'s research on the VOC emission inventories on restaurant scales, there are three methodologies associated with customers, kitchen stoves, and cuisine types which are given as Equations (4)–(6) respectively. See below:

$$S_{person-scale} = Restaurant\ category \times N_c \times EF_{person} \quad (4)$$

$$S_{kitchen\ stove-scale} = \sum N \times a \times t \times EF_{kitchen\ stove} \times 365 \quad (5)$$

$$S_{hour-scale} = \sum N \times t \times EF_{restaurant} \times 365 \quad (6)$$

where N_c is customer dining frequency; N is the number of restaurants for each scale; a is the number of kitchen stoves, and t is the working time. In addition, according to the

aforementioned distribution of the percentage of the city population dining in restaurants per week, a value of approximately 100 times/year was obtained for citizens eating in a restaurant.

In this research, the authors obtained the N_c value from Meituan APP. However, the current literature has limited information to obtain the kitchen stove and restaurant scale data. Thus, the research chose the $S_{person-scale}$ method to calculate the VOC emissions.

2.2.3. PUDP Identification

Patch, a term fundamental to landscape ecology, is defined as a relatively homogeneous area that differs from its surroundings [28]. The theory of urban potential patch is built on the basic principles of landscape ecology, which can help define public spaces that are currently underutilized but have potential value (including economic, cultural, and environmental value). To categorize the space along the Jinjiang River and Fu River in Chengdu, this research involved the theory of urban potential patch. It defined three types of potential urban development patches (PUDPs): open PUDP, landscape PUDP, and conflict PUDP. The open PUDP refers to the urban public space and open space outside of buildings [29]. It supports multiple functions such as maintaining urban ecology, carrying place culture, social and economic services, disaster prevention, etc. It allows people to communicate, relax, and gather. Typical open PUDPs include plazas, corner space, road crossing space, roadside space, etc. Landscape PUDP refers to the urban public space that carries the landscape function and has a green coverage rate of more than 60% [30]. The area of a single landscape PUDP is generally less than 2000 square meters. Typical landscape PUDPs include: open lawn, space under street trees, street corner parks, and independent green spaces such as planters. Conflict PUDP refers to the urban public space that is not fully developed or functioning. Generally, there is minimal planting and pavement in these spaces [31]. Typical conflict PUDP includes the transition space between the buildings and the city, the roof space, the overpass coverage space, parking space, etc.

Based on the existing related studies, this research proposed PUDP categorization criteria according to five factors: pavement, green coverage, land area, waterbody, and use efficiency. The criteria of categorization are shown as follows (Table 2). Based on the remote sensing image of the Google satellite map, researchers divided the Jinjiang District and Wuhou District of Chengdu into 1373 rectangular units of 50 m × 50 m, totaling 3,432,500 square meters. According to the PUDP categorization factors and related weighting criteria, this research regarded units that received 0 to 1 point as conflict PUDPs, units that received 2 to 5 points as open PUDPs, and units that received 6 to 8 points as landscape PUDPs.

Table 2. The factors and weighting criteria of the categorization of PUDP (source: authors).

PUDP Categorization Factors	Weighting Criteria
Pavement	Cement (0); Stone, brick, and concrete (1); Cobblestone and permeable brick (2)
Green coverage rate	Less than 30% (0); between 30% and 60% (1); More than 60% (2)
Land area	Hardscape above 2000 square meters (0); Landscape space below 2000 square meters (1)
Waterbody	No waterbody (0); Some waterbody (1)
Use efficiency	Low (0); High (1); Extremely high (2)

Within all the units, there were approximately 23% of them that were regarded as valid study units (mainly including outdoor or public space). Then, the criteria of categorization were applied to all the valid study units to calculate their points (Figure 6 and Table 3). The results showed that, within these 1373 units, there were 621 units of open PUDP (totaling 552,500 square meters), 427 units of landscape PUDP (totaling 1,067,500 square meters), and 325 units of conflict PUDP (totaling 812,500 square meters) (Table 4 and Figure 7). As

shown in the results of PUDP categorization, almost all the areas along the Jinjiang River and Fu River were densely covered by different PUDPs.

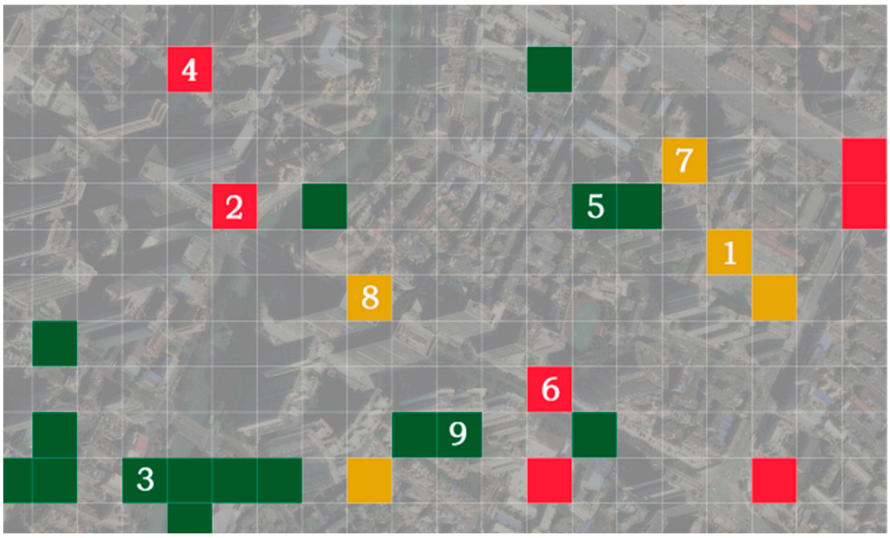

Figure 6. The example of study unit generation and PUDP categorization (source: authors).

Table 3. The example of PUDP calculation and categorization (source: authors).

Study Unit	Pavement	Green Coverage Rate	Land Area	Waterbody	Use Efficiency	Overall Points	PUDP Type
Unit 1	0	0	0	0	0	0	Conflict
Unit 2	1	1	0	0	1	3	Open
Unit 3	2	2	1	1	2	8	Landscape
Unit 4	1	1	1	0	2	5	Open
Unit 5	2	2	1	0	2	7	Landscape
Unit 6	1	1	1	0	1	4	Open
Unit 7	0	0	0	0	1	1	Conflict
Unit 8	0	0	0	0	0	0	Conflict
Unit 9	2	2	0	0	2	6	Landscape

Table 4. Number, area, and proportion of different PUDPs in Jinjiang and Wuhou District (source: authors).

PUDP Type	District	Number of Units	Area (m^2)	Proportion
Open (red)	Jinjiang District	457	1,142,500	44.7%
	Wuhou District	164	410,000	38.2%
Landscape (green)	Jinjiang District	240	600,000	23.5%
	Wuhou District	187	467,500	43.6%
Conflict (yellow)	Jinjiang District	325	812,500	31.8%
	Wuhou District	78	195,000	18.2%

Therefore, we started with designing the different PUDP's physical spaces and used each type of PUDP as a prototype to achieve urban planning improvement along the Jinjiang River and Fu River by involving the food POIs.

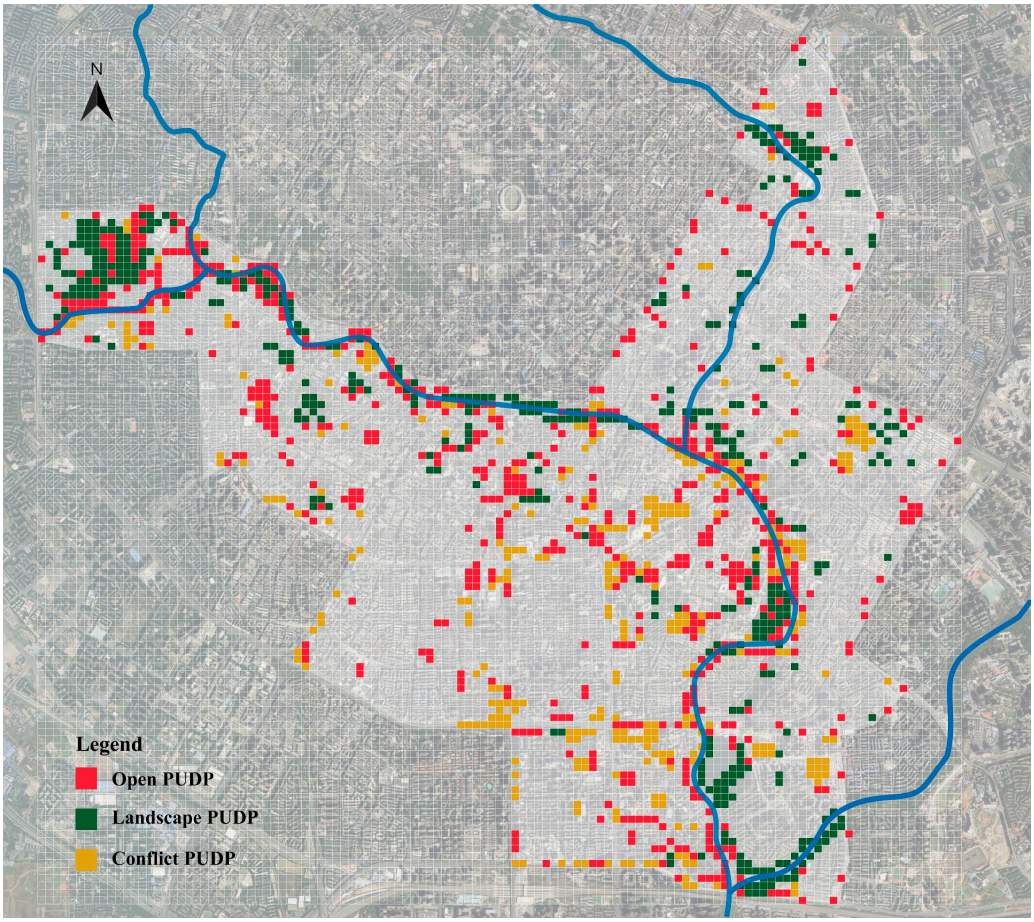

Figure 7. Mapping of the PUDPs in Jinjiang District and Wuhou District of Chengdu (source: authors).

2.3. Data Analysis

Based on the mapping of food POIs, 15 high-density food hubs, and three types of PUDPs, a buffer model indicating the local food culture influence was calculated by giving 15 food centers a 1000 m influence range and then calculating the number of food POIs covered under that influence radius. As shown in the table below, we obtained the specific numbers of the PUDPs, the food POIs, and the VOCs in each food center's influence buffer (Table 5). Meanwhile, the Pearson correlation analysis was conducted to study the relationship between PUDPs, food POIs, and VOCs in the study area (Table 6). From the results, it was concluded that the VOCs and POI have a strong correlation, and both have a significant negative correlation with open PUDP. However, the landscape PUDP and conflict PUDP did not show an obvious relationship with food POI and VOCs.

Learning from the significantly negative correlation between food POI, VOCs, and open PUDP, it was possible that the more open PUDP likely helped reduce VOCs. According to the categorization criteria of open PUDP, an open PUDP includes an even distribution of hardscape, green space, and water features. It supports citizen, commercial, and cultural activities while maintaining ecological and environmental functions at the same time. In other words, compared to pure landscape PUDPs and conflict PUDPs, the open PUDPs in cities achieve a balance between urban and nature, which could control the VOCs due to food spots in a gentle but effective way.

Table 5. Food POI density, PUDP type, and VOCs statistics (source: authors).

Food Center ID	POI Number	Open PUDP	Landscape PUDP	Conflict PUDP	VOCs
1	116	53	63	13	113,436.69
2	89	80	36	12	71,490.15
3	129	72	45	17	122,115.50
4	162	46	37	17	88,839.17
5	103	73	46	33	94,346.08
6	91	80	19	55	82,673.64
7	138	105	52	95	151,254.03
8	90	61	11	54	91,529.39
9	229	22	27	7	268,312.30
10	367	20	20	5	410,282.10
11	200	47	38	38	217,835.29
12	179	41	46	36	167,497.35
13	162	53	34	27	162,483.39
14	146	38	30	20	119,590.22
15	181	66	64	45	185,154.98

Table 6. Pearson correlations analyses of food POI, VOCs, and PUDP.

	POI	Open PUDP	Landscape PUDP	Conflict PUDP	VOCs
POI	1	−0.700 ** 0.004	−0.158 0.574	−0.355 0.194	0.966 ** <0.001
Open PUDP	−0.700 ** 0.004	1	0.314 0.255	0.695 ** 0.004	−0.624 * 0.013
Landscape PUDP	−0.158 0.574	0.314 0.255	1	0.113 0.687	−0.170 0.544
Conflict PUDP	−0.355 0.194	0.695 ** 0.004	0.113 0.687	1	−0.270 0.331
VOCs	0.966 ** <0.001	−0.624 * 0.013	−0.170 0.544	−0.270 0.331	1

* Correlation is significant at the 0.05 level (2-tailed). ** Correlation is significant at the 0.01 level (2-tailed).

3. Discussion

As shown in the correlation study, it was concluded that food POI and VOCs have a significant negative correlation with open PUDP. This indicates that the more open PUDP could likely help reduce VOCs. According to the PUDP categorization criteria proposed in this research, the open PUDP includes an even distribution of hardscape, green space, and water features. It supports citizen, commercial, and cultural activities while maintaining ecological and environmental functions at the same time. In this way, the open PUDP could provide more space for local restaurants so the cooking environment could be more efficient and environmentally friendly, which controls the VOCs from the start.

On the other hand, a certain amount of green space and water features in open PUDPs could reduce the air pollution caused by VOCs, while the commercial function of open PUDPs could help restaurants attract visitors, stimulating the vitality of the local catering industry while controlling VOCs. Compared to open PUDP, the landscape PUDP is more nature focused. Although it provides more green and blue space for air pollution governance, it does not guarantee enough space for the necessary development and optimization of local catering, which affects VOCs' control. Like the landscape PUDP, the conflict PUDP fails to reduce VOCs comprehensively. The conflict PUDP does not have enough green space for air quality control. It may provide space for restaurant renovation, but these spaces lack commercial potential because of their accessibility and location. Therefore, to control the VOCs problem related to the local food industry, increasing the number of

open PUDPs and optimizing the spatial design of open PUDPs are necessary for future urban planning and renovation. Some existing studies have addressed that urban green or natural landscape space could reduce urban air pollution, but this research proposed a different point of view by studying the relationship between food POI, VOCs, and a new concept, "PUDP", comprehensively. Urban green space may contribute more to urban air quality control at a macro level. However, when discussing the food culture and related VOCs problems specifically, the urban open PUDP plays a more important role. Based on the results of this research, it should be suggested that Chengdu adjusts its land use and urban space planning based on the PUDP theory. Within the study area and broader region around, the proportion of open PUDPs should be increased. The open PUDP's location should coordinate with food centers, and the spatial design of open PUDPs should be carefully polished based on the requirements of the local catering industry.

4. Highlights and Future Work

This study explored the spatial distribution of the traditional restaurants in Chengdu, China. Information such as restaurant names, locations, popularity, and price were obtained and used for geospatial mapping, calculation, and analysis by extracting food-related data from social media. Based on the geospatial and data analyses, the VOCs of every high-density food hub were estimated. Meanwhile, this research proposed a principle of defining the PUDP with the weighted calculation of different urban space features. It categorized the study site into three types of PUDP: open PUDP, landscape PUDP, and conflict PUDP. In this way, the researchers obtained the data on food POI, VOCs, and PUDP categorization, then the correlation analysis of PUDP, food POI, and VOCs was conducted. From the analysis results and conclusion, it was learned that, compared to landscape and conflict PUDP, the more open PUDP could likely help reduce VOCs.

In future urban ecology construction and urban design, the environmental and air quality and culture should receive more attention. VOCs of restaurants is one of the irreplaceable factors for practitioners to consider, especially for cities with rich food culture and resources such as Chengdu. The conclusion of this research provided a possible direction for controlling air quality from the perspective of food culture and ecological urban design. It addressed that urban open space design and renovation could effectively affect the catering industry's development and VOCs could reduce and better construct the urban ecology. There are some suggested urban design and planning strategies that could control the catering related VOCs according to the research conclusion. For physical urban space, feasible strategies include landscaping and transforming the gray space under the viaduct, optimizing the commuter space around the subway station, developing urban roof and wall greening, and establishing urban agricultural systems such as rooftop farms, community farms, and riverside tea gardens. From the perspective of culture and society, the government, enterprises, social organizations, and universities could unite together to create a communication matrix related to food culture and air quality protection, including the developing of relevant applications and the designing of innovative exhibition and experience spaces associated with food culture.

This research innovatively integrated the perspectives of food culture, urban ecology, and geospatial analysis to address a new perspective to construct the urban ecological system. This research's results and methods could inspire scholars and practitioners to think about the relationship between food culture, air quality control, and urban land use in proposing sustainable, flexible, and reasonable design solutions for future cities.

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