THE RATIONALITY OF URBAN FINANCIAL NETWORK LAYOUT BASED ON POI DATA

Jinbo Liu[1,2], Shishuo Xu[1,2,*], Haizhi Ma[3,2], Sikai Wang[3,2], Fangning Li[3,2]

[1]School of Geomatics and Urban Spatial Informatics, Beijing University of Civil Engineering and Architecture, 15 Yongyuan Road, Beijing, 102616, China; 2108570021078@stu.bucea.edu.cn; xushishuo@bucea.edu.cn.
[2]Key Laboratory of Urban Spatial Informatics, Ministry of Natural Resources of the People's Republic of China, 15 Yongyuan Road, Beijing, 102616, China.
[3]Beijing Urban Construction Exploration & Surveying Design Research Institute Co. Ltd, Beijing, 100101, China; 19414973@qq.com; wangsikai@cki.com.cn; 64877558@qq.com.

KEY WORDS: Rationality of spatial layout, Travel vitality index, Financial outlets, Point of interest, Urban functional areas

ABSTRACT:

Financial outlets are branches or business outlets of financial institutions such as banks, investment and finance companies and insurance companies in cities, which are used to provide a variety of financial services and businesses. The location of financial outlets is usually determined on the basis of factors such as population density, commercial areas, residential areas and transportation convenience. As an important carrier of urban financial services, the rationality of the layout of financial outlets can reflect the financial needs and behavioral patterns of people in the city. Urban functional area is a product after urbanization, different from urban land use type which focuses on the classification of urban land use through natural conditions, urban functional area mainly analyzes the internal spatial structure of the city, focusing on the discernment of the dominant functions within the built-up area of the city. By categorizing urban functions such as residence, commercial service and industry, the spatial distribution of urban functions can be grasped to provide support for urban planning and development. Urban functional areas can reveal human behavior patterns, needs and preferences in different areas. The current research on financial outlets mainly focuses on the accessibility and coverage of financial outlets, and researchers treat financial outlets as spatially undifferentiated points, ignoring the problem of spatial heterogeneity of financial outlets within different functional zones. When studying the rationality of the layout of urban financial outlets, considering different functional zones within the city can better meet the financial needs of residents, enterprises and institutions in the region and improve the accessibility and convenience of financial services. Analyzing the comprehensive service capacity of financial outlets within different functional areas is obviously insufficient in the current study, which is not conducive to the configuration planning of financial outlets and the promotion of the accessibility of urban financial services. The wide application of Point of Interest (POI) data in spatial analysis provides a new perspective for the study of urban financial outlets, for this reason, this paper analyzes and researches the current situation and rationality of the spatial layout of financial outlets based on POI data, under the perspective of the functional areas of the city, and combined with the population travel vitality index. The Term Frequency-Inverse Document Frequency (TF-IDF) algorithm is used to process the POI data to generate the urban functional area, on the basis of which the travel vitality index in the city is calculated by combining the population coverage and road network density, so as to judge the reasonableness of the layout of urban financial outlets. This helps us to better understand the behavioral decision-making process and social interaction of human beings about financial life in the city, and provides guidance and decision-making support for urban financial layout planning, financial public services and financial policies.

1. INTRODUCTION

At the end of the twentieth century, the first online bank was established in the United States, announcing the arrival of the era of cyberfinance. Since then, e-finance and digital financial services have been growing all over the world, especially in technological and cyber developed countries. Online financial services have brought users a good experience of using them with their convenience and speed, which has greatly changed people's lifestyle(Chen and Tsai, 2016). The rise of online banking financial services had brought an impact on the business of traditional financial physical outlets, online finance was faster and more efficient compared to traditional physical outlets(Bradley and Stewart, 2003), the rise of these new technologies and online services has led to some extent to the uneconomical and irrational layout of the traditional financial outlets, especially in economically and Internet-developed regions, where the fast pace of work and life and high time costs make more and more people choose online financial services, and the unreasonable setting of traditional financial outlets in the region will result in a waste of market resources(Andal-Ancion et al., 2003). The manual service channel of the financial industry was the starting point for the development of traditional commercial services. At present, online financial services didn't fully cover all basic financial services(Pan et al., 2021), especially the information involving user privacy or large financial serviced still need to be handled through the network. Even in some of the most developed regions of China's network economy, there were still a number of middle-aged and elderly people who had difficulty using mobile smartphones(Jiang et al., 2021), as well as teenagers and people with disabilities. In less economically developed areas, a large number of people who couldn't access convenient network services(Liu et al., 2021b) or operated mobile computer APPs(Kong and Loubere, 2021), such as those with a relatively low level of literacy, still took financial outlets as an important way for them to handle commercial financial services. It can be seen that financial outlets currently play an irreplaceable and important role in online finance, and are the basic business operation platform on which the current commercial and financial industries rely.

Urban functional area is a product of urbanization, and geospatial big data has been applied in the identification and research of urban functional area(Gao et al., 2017). Scholars have explored and analyzed the data of social media(Chen et al., 2017), cell

*Corresponding author: xushishuo@bucea.edu.cn

phone signaling(Yuan et al., 2020), transportation(Liu et al., 2020), and Point of Interest (POI)(Wang et al., 2021), and constructed a system of methods for identifying the types of functional zones in the city, etc. People used mobile phone data to explore the correlation between the spatial and temporal changes in population dynamics and land use, and improved the functional zoning rules of urban land(Toole et al., 2012). Some people used clustering algorithm to quantitatively analyze the commuting flow of urban residents' trips, the relationship between trips to different locations, and the relationship between trips and land use based on automobile GPS data and bus and subway swipe card data(Liu et al., 2009). Some scholars have elevated awareness of network accessibility through social media check-ins to more clearly depict the urban fabric and associated socio-economic manifestations, further dividing streets into functional zones with annotations based on functional connectivity in different types of active land uses(Shen and Karimi, 2016). Several studies have developed a fine-scale population distribution mapping methodology by combining functional zones (FZs) with NTL data, high-resolution satellite imagery and LBS data(Song et al., 2019).

The wide application of Point of Interest (POI) data in spatial analysis provides a new perspective for the research of urban financial networks. Point of interest (POI) data is a description of geospatial elements in the form of point entities, including names, addresses, coordinates, administrative districts, categories, and other spatial and attribute information, and its categories can well respond to all kinds of activities in the city, and it is a kind of data of better quality in the study of urban functional areas, and a large number of scholars have carried out different types of researches on the city based on POI data. Some scholars proposed a new method to mine the co-location patterns (CPs) of urban activities with POI data(Chen et al., 2020). The researchers proposed a method to identify and analyze urban functional areas based on POI functional type ratio and frequency density, and then they took Guangzhou Economic and Technological Development Zone as an example, the main functions and geographical distribution patterns of the refined functional zones were analyzed(Hu and Han, 2019). For the rich spatial features extracted from POIs, the researchers established an innovative framework to detect urban land use distribution at the scale of Traffic Analysis Zones (TAZs) by integrating Baidu POIs and Word2Vec models(Yao et al., 2017).

Currently, the main focus for the travel vitality index is between the vitality index and the ecological index(Zhang et al., 2022). Some scholars have laid the groundwork for a quantitative exploration of community street vitality by integrating streets into a single vitality index to highlight their social characteristics(Liu et al., 2021a). In addition to this, some researchers have used bike-sharing data to study the spatio-temporal dynamics of urban vitality(Zeng et al., 2020), as well as multi-source big data to study urban vitality(Wang et al., 2023). In addition to this, some researchers have used bike-sharing data to study the spatio-temporal dynamics of urban vitality, as well as multi-source big data to study urban vitality. All these show that understanding the characteristics of urban vitality can provide a scientific basis for urban planning and decision-making, and can enhance the sustainable development of cities and improve the quality of life of residents.

In the current research content, the study of financial outlets mainly focuses on the accessibility and coverage of financial outlets, and researchers treat financial outlets as spatial points without distinction, ignoring the spatial heterogeneity of financial outlets in different functional areas. The research of the spatial layout of financial outlets through the urban functional area constructed by POI data is not only conducive to the conduct of business and the provision of service efficiency, but also brings convenience and speed to the life of urban residents, and has a very important position in the integration of urban resources and the process of realizing the strategic economic goals. In order to study the rationality of the layout of financial outlets in the city, our spatial layout analysis model of urban financial outlets based on POI data takes full account of the functional area to which the financial outlets belong and the heterogeneity of the population's travel dynamics, which makes the analysis of the spatial layout more accurate and provides reference suggestions for the planning of the city's financial services, and for the allocation of financial institutions' outlets.

The rest of the paper is organized as follows. Section 2 describes the study area and experimental data used in this study. Section 3 describes the research methodology. Section 4 discusses and analyzes the layout of urban financial outlets and analyzes the rationality of the current layout of financial outlets. Section 5 provides an overview of the main findings and provides an outlook for future research.

2. STUDY AREA AND EXPERIMENTAL DATA

2.1 Study area

The study area of this research is located in Handan City, Hebei Province, China. Handan is a city in the southern part of Hebei Province, known for its rich topography and unique geographical location. The total area of Handan City is 12,066 km^2. According to the seventh national census bulletin of Hebei Province, as of 2021, the resident population of Handan is about 9.414 million people. Handan City is located in Hebei Province, bordering Shandong, Henan and Shanxi Provinces, and is an important transportation hub where the four provinces meet. Figure 1 illustrates the study area of this experiment.

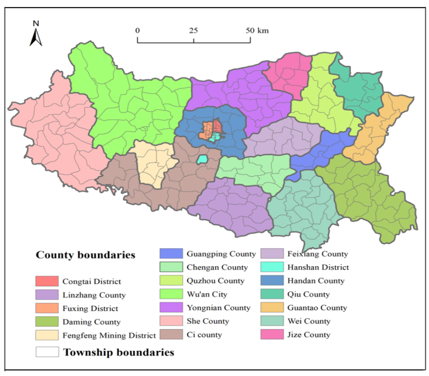

Figure 1. Counties and townships in Handan City.

This contribution has been peer-reviewed.
https://doi.org/10.5194/isprs-archives-XLVIII-1-W2-2023-353-2023 | © Author(s) 2023. CC BY 4.0 License.

Handan city is crisscrossed with transportation roads, and various grades of highways, national highways, and railroads are distributed in an orderly manner to form a convenient transportation network, and Handan is also the only city with both railroads, highways, and airways in the four-province junction area. The unique geographic location leads to a variety of travel modes of the residents, and the functional attributes of the city are obvious, which makes the financial structure of Handan City has local uniqueness and complexity, so it is important for us to study the layout of financial outlets in Handan City, which will provide theoretical and methodological help for the future study of the spatial layout of financial outlets in other regions.

2.2 Experimental data

The 2020 WorldPop population data for Handan (from https://www.worldpop.org/), the 2020 financial outlets data and POI data for Handan, and the road data for Handan (https://www.openstreetmap.org/) were used in this study. A road map of the Handan City in 2020 is shown in Figure 2.

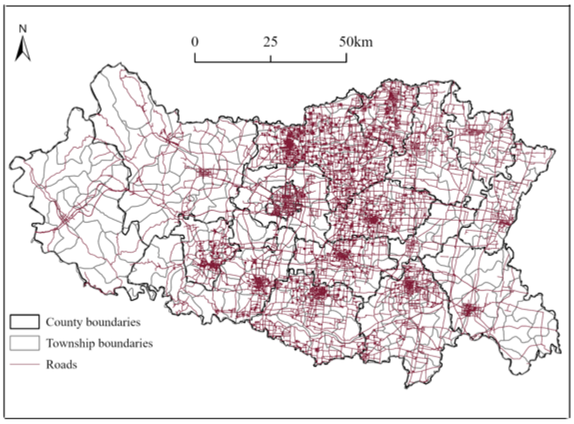

Figure 2. Handan road map in 2020.

POI data is obtained from Amap data through crawler technology, the data content includes latitude and longitude, belonging to the category, address, name and other basic information, a total of 1,340,269 data, as shown in Figure 3. The financial outlets data is obtained from POI data obtained from Amap, after removing duplicated and wrong address point data is 23,692 as the spatial distribution data of the financial outlets.

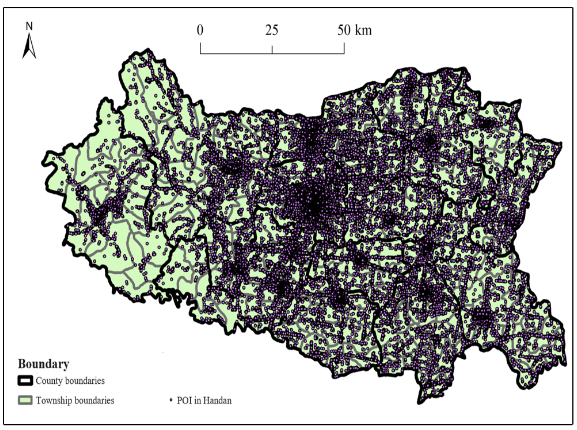

Figure 3. POI in Handan.

3. METHODOLOGY

Based on POI big data, this paper proposed the use of TF-IDF algorithm to calculate the weights of various types of POIs within the city, and through the processing of POI data, we got the location data of financial outlets and other basic data for discriminating the functional areas of the city, and optimized the results of identifying the functional areas. Then WorldPop population data and OpenStreetMap (OSM) road network data were integrated to calculate the travel vitality index population travel vitality index, which was used together with the standard deviation ellipse, kernel density estimation, population coverage and the spatial coverage of financial outlets to analyze the rationality of the spatial layout of urban financial outlets (Figure 4).

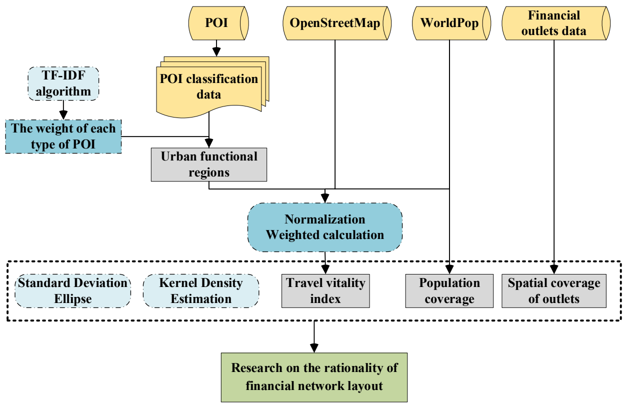

Figure 4. An overall framework for conducting this study.

3.1 Term Frequency-Inverse Document Frequency

The Term Frequency-Inverse Document Frequency (TF-IDF) algorithm is frequently employed in information retrieval and text mining to evaluate the importance of a word to a document in a collection of documents. As a point-shaped geographical entity, POIs are assigned weights based on public perception, but due to the complexity of data types and the large amount of data, the effect of this method is closely related to the weights set by the researcher, which is excessively subjective. In the TF-IDF algorithm, each research unit is treated as an individual, and the composition of POIs within the unit is fully considered, and combined with the distribution of various types of POIs in the total space, the weight values of various types of POIs can be derived for each research unit. Using the TF-IDF algorithm to statistically analyze the POIs both locally and as a whole, the weights of POIs can be derived more objectively (Jing et al., 2002).

We reclassified the obtained POI data of 14 categories and finally divided them into 5 categories, which are commercial services, living, traffic, common, and industrial. The IDF values of each category of POIs are obtained by calculation as in Table 1. On this basis, we further realize the division of the city's functional areas.

Table 1. IDF for different types of POIs.

Commercial services	Living	Traffic	Common	Industrial
0.7071	0.3126	0.3035	0.1158	0.4814

3.2 Urban Functional Area Identification

The type of urban functional area is mainly determined by the category and number of POIs, and the study area is divided into 7,275 1.5 km^2 spatial grid cells. Utilizing the TF-IDF model for weighting cell-based POI counts, contrasted to conventional weight assignment techniques, both the distribution of POIs in the whole area and their density in the spatial grid cells are considered, so that the urban functional zones can be identified more accurately.

Using Equation (1) - Equation (3), the weighted value of each type of POI within each spatial grid cell, i.e., frequency density, is calculated, and the urban functional area is divided according to the frequency density. Initially, the area without POI is screened out and designate them as no data area; when the frequency density of a certain category of POI surpasses 50%, the attributes of that categories of POI will be set as the attributes of the functional area, including common, commercial services, industrial, living, traffic and other five categories of single functional area; when there is no certain category of POI with a weighting of more than 50%, there will be two of them with a weighting of POI at 30%~50%, these two categories are denoted as the joint functional area, and the rest are categorized as mixed functional areas.

$$tf_{i,j} = \frac{n_{i,j}}{\sum_k n_{k,j}} \quad (1)$$

$$idf_i = \lg \frac{|D|}{\left|\{ j : t_i \in d_j \}\right|} \quad (2)$$

$$tfidf_{i.j} = tf_{i,j} \times idf_i \quad (3)$$

i denotes a POI of a certain category; j denotes a spatial grid cell; n_{ij} denotes the number of occurrences of POIs of category i in spatial grid cell j; $\sum_k n_{k,j}$ denotes the sum of occurrences of all POIs in spatial grid cell j; D denotes the total number of spatial grid cells; $\left|\{j: t_i \epsilon d_j\}\right|$ denotes the whole number of spatial grid cells containing POIs of a category.

3.3 Kernel Density Estimation

Kemel Density Estimation (KDE) is an analytical method that reflects the characteristics of regional spatial distribution in a visualized form by calculating the distribution density of the elements within the delineated area(Chen, 2017). KDE is widely used to predict the way of aggregation of the measured point data in the space, and through the method of kernel density estimation, it can be both carried out for the calculation of the density of the line elements, and also be applied to the calculation of the density of the point elements. It can reflect the relative concentration of various types of POI point data in the spatial layout, which is more intuitive when studying the spatial layout of financial outlets.

3.4 Travel Vitality Index

Different functional areas have different travel attractiveness for the population, and the Travel Vitality Index model uses the number of people in a spatial grid cell and the richness of the road network, normalizes the two, and then weights them. The weighting coefficients for different functional areas are then multiplied.

$$G_{xm} = \frac{G_m - G_x^{\min}}{G_x^{\max} - G_x^{\min}} \quad (4)$$

$$G_m = G_{xm} \times Q_y \left(x = 1,2; y = 1,2,3,\cdots,8; m = 1,2,3,\cdots,n \right) \quad (5)$$

where $x_{1,2}$ denotes population size and road network density, respectively; m denotes the number of the spatial grid cell; G_m denotes the value of cell m; G_x^{max} denotes the maximum value of category x, G_x^{min} denotes the least value of category x, and G_{xm} denotes the normalized value of category x of spatial grid cell m; Q_y denotes, in order, the weight of each of the 8 types of functional areas with respect to the travel vitality index, or, in the case of a mixed-functional area, the average of the two single functional areas; and C_m denotes the travel vitality index of spatial grid cell m.

3.5 Standard Deviation Ellipse

Standard Deviation Ellipse (SDE) is a classic method used to study the directional characteristics of the spatial distribution of objects(Yuill, 1971), often used to consider the central tendency, direction and discrete tendency of the elements in the spatial distribution. In order to study the spatial distribution of the directional characteristics of the financial outlets in Handan City to construct the SDE in research.

The standard deviation ellipse contains the long axis, the short axis, and the center of the circle of the ellipse, and the standard deviation ellipse method measures the directionality of the distribution among the elements. When performing standard deviation ellipse analysis, the parts that usually need to be concerned and analyzed include the three elements of the angle of rotation θ, the standard deviation along the long axis and the standard deviation along the short axis. The long half-axis of the ellipse in this method is used to indicate the direction of the distribution of spatial data, while the range of the distribution of data is indicated by the short half-axis, and the position of the standard deviation ellipse changes when the spatial center of gravity of the financial outlets is changing. The area size of the standard deviation ellipse can reflect the degree of concentration of the overall elements of the spatial pattern, and a small area means that the distribution of each element is closer to the center.

4. RESULTS AND DISCUSSION

In this section, we analyze the results of identifying the functional areas of the city, the travel vitality index of the residents, the KDE of different functional areas and the SDE of the financial outlets in Handan.

4.1 Travel Vitality Index within Handan City Functions

4.1.1 Functional area identification results

Based on TF-IDF algorithm and POI frequency density, the identification results of Handan urban functional zones are shown in Figure 5. The findings indicated that: Handan urban functional areas were 7275 in total, with the spatial distribution of two categories of commercial and public services and joint functional areas as the main ones; the joint functional areas were 3629 in total, with a relatively decentralized distribution, wide coverage, and staggered layout with the single functional zones; the single functional areas were 2170.There were 1,552 commercial service functional areas and 1,152 industrial functional areas, which were the two most numerous functional areas. The commercial service functional areas were mainly concentrated in the center of Handan city and each county and district, which were closely related to the commercial development of Handan city. Industrial functional areas accounted for a relatively large proportion of the area centers in Handan city and areas closer to the city. The distribution of public functional areas was more dispersed, indicating a certain degree of spatial balance; 926 mixed functional areas were mostly located in the centers of various regions; and there were 216 no data areas, mainly in water systems, mountainous areas, farmland and other areas, which were basically unrelated to the financial structure of the city.

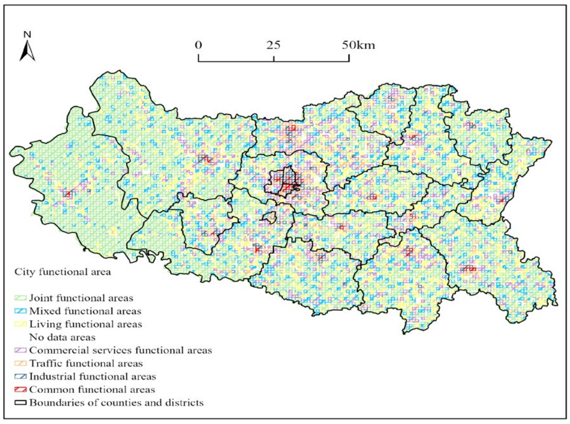

Figure 5. Handan City urban functional areas.

4.1.2 Analysis of population coverage and road network density

A 1 km * 1 km spatial grid cell was used as the basic spatial unit, and the road network density and population coverage within the spatial unit were calculated separately. Road network density is a visual indicator of the sparseness of the transportation road network in a region. The higher the density of a region's transportation road network, the denser the region's transportation road network is, including motor vehicle lanes, motorcycle lanes, bicycle lanes, sidewalks, etc., indicating that the higher the frequency of population and vehicle trips within the region, the higher the Travel Vitality Index. Since the spatial data collection process of WorldPop population takes into account the aggregation of residential population, traveling population, check-in population, etc. in a certain area, the population coverage indicates that the higher the frequency of population and vehicle trips in the area, and the higher the corresponding travel vitality index. The population coverage situation and road network density are shown in Figure 6 and Figure 7, respectively.

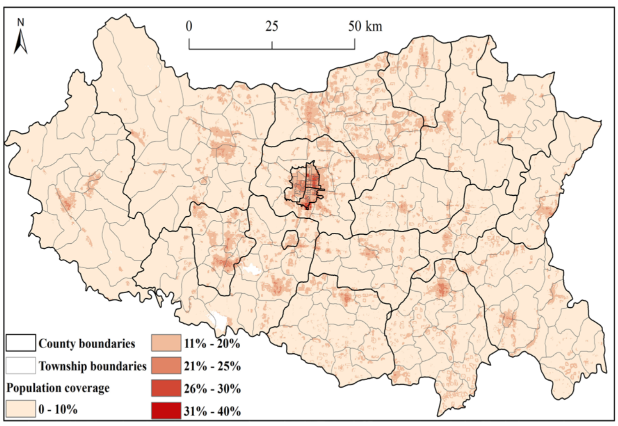

Figure 6. Population coverage

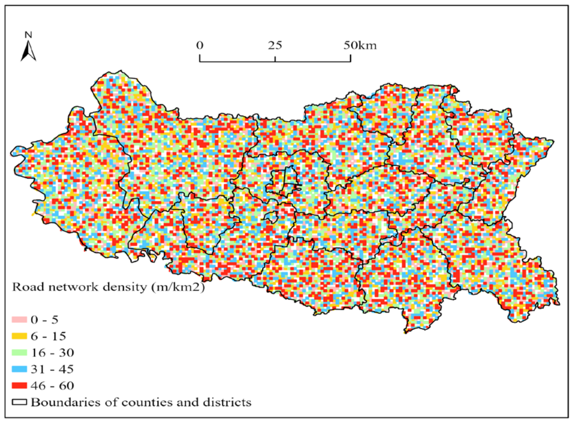

Figure 7. Road network density

4.1.3 Calculation of the travel vitality index

The level of service of a financial outlet can be determined by the Travel Vitality Index of the areas, where the density of the road network is positively correlated with the travel vitality of the areas, i.e. areas with a high density of road network per unit have a higher Travel Vitality Index. For example, commercial buildings, shopping streets, etc. There are also some areas with high density of unit road network, but mainly used as land for transportation facilities, such as transportation hubs, overpasses and so on. The travel vitality of these areas is not high. This paper established the travel vitality index model, through the normalization and superposition analysis of the number of population and road network density, adding the consideration of urban functional areas, and finally obtaining a more fine-grained spatial distribution of travel vitality of the population in urban functional areas (Figure 8).

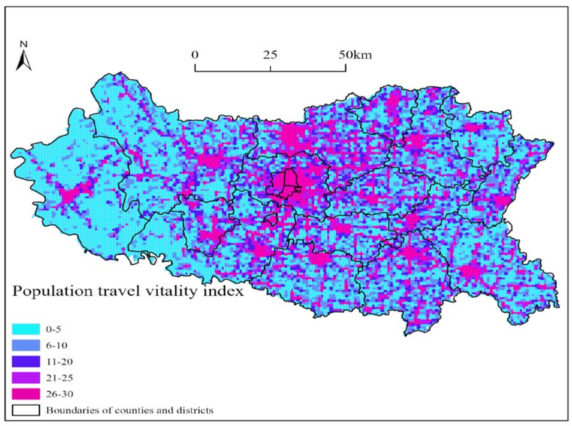

Figure 8. Distribution of travel vitality index

4.2 Analysis of KDE and SDE

Performing KDE on the classified five categories of POIs and visualizing the kernel density results as in Figure 9, we could find the spatial distribution of each category of POIs.

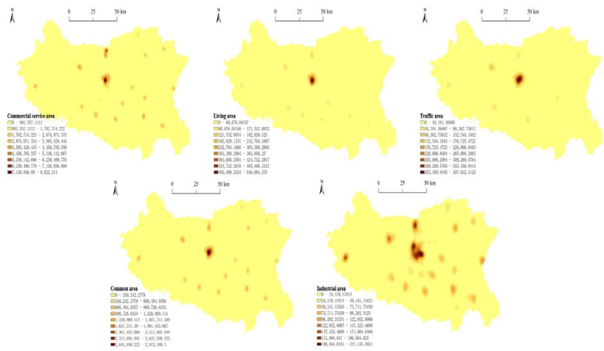

Figure 9. Results of KDE

The SDE of Handan financial outlets (Figure 10) was located in the central area of Handan city, with the main axis biased towards northwest-southeast direction, the longitude of the center point was 114.51°, the latitude of the center point was 36.58°, the long axis was 45.60km, the short axis was 23.03km, the angle of the direction was 96.81°, and the oblateness of the SDE was 0.495. From the Handan financial outlets, the location and shape of the SDE of the data showed that the center of gravity of the distribution of financial outlets in Handan City was located in the central city of Handan County within the Fuxing District and the Handan Mountain District. The trend of the center of the outlets was concentrated in Handan County, and the surrounding outlets showed a tendency of diffusion. The long axis of the standard deviation ellipse was in the northwest-southeast direction, reflecting the distribution direction of financial outlets in Handan City was biased in the northwest-southeast direction, the directional trend was more obvious, the ellipse short half-axis was longer, and the distribution of financial outlets was more dispersed, which also indicated that the distribution of financial outlets in Handan City was concentrated in Handan County in the geographic center of Handan City, and the surrounding counties and townships were concentrated in the central urban area of Fuxing District and Hanshan District, and the surrounding outlets were spreading. The distribution of financial outlets in the surrounding counties and townships was more scattered, with a large degree of dispersion and uneven spatial distribution.

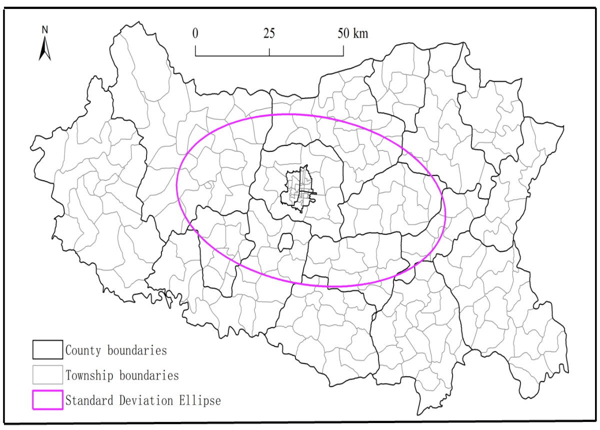

Figure 10. Results of SDE

5. CONCLUSIONS AND FUTURE WORK

In this paper, we firstly pre-processed the acquired POI data, divided it into five types of functional areas: commercial service, public, industrial, transportation, and residential, and use the TF-IDF algorithm to calculate the weights of the POI data and generated the functional areas of Handan, analyzed the functional areas of Handan with the population of Handan, and the transportation and road network of Handan. And then constructed a population travel vitality index map of Handan, and then analyzed the population travel vitality index map against the layout of financial outlets in Handan. Financial outlets layout to analyze the population travel vitality index map. Through manual visual identification, we found that the areas with high population travel vitality index overlap with the dense areas of financial outlets, which indicates that financial institutions are more inclined to lay out their outlets in areas with higher population mobility and convenient transportation to better serve the population demand. Against Amap, we analyzed that the areas with high population travel vitality indexes coincide with areas of concentrated economic activities such as commercial centers, office areas, and industrial areas (automotive services), which leads to a greater concentration of financial outlets in these areas to satisfy business needs and the convenience of financial transactions. We also find that areas with high population travel vitality indexes are associated with financial service demand, and areas with high population travel vitality indexes are usually accompanied by more frequent movement of people and business transaction activities, which can lead to higher demand for financial services, such as loans, payments, and savings.

The travel characteristics of population groups within different functional areas also differ in their demand for financial services, and financial institutions are more likely to set up their outlets in business service areas in order to provide financial services for business activities. For example, business people are more inclined to look for financial services near commercial center areas, while residents are more in need of convenient financial outlets near their residential areas, which can help enhance the location configuration of financial outlets and optimize the spatial structure of outlets. Financial outlets are usually concentrated in areas with a high density of POI cores in order to provide more convenient financial services in close proximity to other important facilities and services. Conveniently located areas are more likely to attract the establishment of financial outlets as they provide better customer accessibility and easy business communication. Factors such as the degree of development of the transportation network, the coverage of public transportation facilities and road congestion will have an impact on the selection of financial outlets. To sum up, the spatial layout of financial outlets can be analyzed from many aspects, and population, transportation, urban functional areas and POI core density are all important factors affecting the spatial layout of financial outlets. An in-depth study of the interrelationship between these factors can help us better understand and explain the distribution pattern of financial outlets in the city.

The results of this paper show that this kind of POI big data based on the study of the layout of urban financial outlets in the study of the functional area to which the financial outlets belong and the population travel dynamics of the heterogeneity of the problem, the analysis of the spatial layout is more accurate, and it can provide reference suggestions for the planning of urban financial services and the configuration of financial institutions outlets. Considering the functional area to which financial outlets belong helps us to take consumer behavior as the research basis when analyzing the spatial layout of financial outlets. The study of the layout of financial outlets in cities is a topic that requires long-term research, and the functional area to which financial outlets belong has an important impact on the choice of location and layout of outlets by financial institutions. Considering consumer behavior and demand, as well as factors such as convenience of travel, residential demand, business demand and consumption capacity, we can better understand the law of spatial layout of financial outlets and provide financial institutions with a reasonable basis for decision-making. In the future, when studying the layout of financial outlets, we can consider adding media data so that we can gain a deeper understanding of the impact of human behavior on financial space in the research process.

ACKNOWLEDGEMENT

This work was funded by the Beijing Association for Science and Technology Young Elite Scientist Sponsorship Program (BYESS2023008), the Key Laboratory of Urban Spatial Informatics, Ministry of Natural Resources of the People's Republic of China (2023ZD002), China Scholarship Council (03998521001) and Beijing Categorized Development Quota Project (03082723003).

REFERENCES

Andal-Ancion, A., Cartwright, P.A., Yip, G.S., 2003. The digital transformation of traditional business. MIT Sloan Management Review 44, 34.

Bradley, L., Stewart, K., 2003. The diffusion of online banking. Journal of Marketing Management 19, 1087-1109.

Chen, K.-Y., Tsai, S.-B., 2016. Service quality and competitive strategies in online banking, First International Conference Economic and Business Management 2016. Atlantis Press, pp. 174-180.

Chen, Y.-C., 2017. A tutorial on kernel density estimation and recent advances. Biostatistics & Epidemiology 1, 161-187.

Chen, Y., Chen, X., Liu, Z., Li, X., 2020. Understanding the spatial organization of urban functions based on co-location patterns mining: A comparative analysis for 25 Chinese cities. Cities 97, 102563.

Chen, Y., Liu, X., Li, X., Liu, X., Yao, Y., Hu, G., Xu, X., Pei, F., 2017. Delineating urban functional areas with building-level social media data: A dynamic time warping (DTW) distance based k-medoids method. Landscape and Urban Planning 160, 48-60.

Gao, S., Janowicz, K., Couclelis, H., 2017. Extracting urban functional regions from points of interest and human activities on location-based social networks. Transactions in GIS 21, 446-467.

Hu, Y., Han, Y., 2019. Identification of urban functional areas based on POI data: A case study of the Guangzhou economic and technological development zone. Sustainability 11, 1385.

Jiang, X., Wang, X., Ren, J., Xie, Z., 2021. The Nexus between digital finance and economic development: evidence from China. Sustainability 13, 7289.

Jing, L.-P., Huang, H.-K., Shi, H.-B., 2002. Improved feature selection approach TFIDF in text mining, Proceedings. International Conference on Machine Learning and Cybernetics. IEEE, pp. 944-946.

Kong, S.T., Loubere, N., 2021. Digitally down to the countryside: Fintech and rural development in China. The Journal of Development Studies 57, 1739-1754.

Liu, L., Biderman, A., Ratti, C., 2009. Urban mobility landscape: Real time monitoring of urban mobility patterns, Proceedings of the 11th international conference on computers in urban planning and urban management. Citeseer, pp. 1-16.

Liu, M., Jiang, Y., He, J., 2021a. Quantitative evaluation on street vitality: A case study of Zhoujiadu community in Shanghai. Sustainability 13, 3027.

Liu, X., Tian, Y., Zhang, X., Wan, Z., 2020. Identification of urban functional regions in chengdu based on taxi trajectory time series data. ISPRS International Journal of Geo-Information 9, 158.

Liu, Y., Luan, L., Wu, W., Zhang, Z., Hsu, Y., 2021b. Can digital financial inclusion promote China's economic growth? International Review of Financial Analysis 78, 101889.

Pan, J., Huang, W., Li, X., Li, R., 2021. Spatial distribution and regional accessibility measurement of financial services in china. Arabian Journal of Geosciences 14, 1-11.

Shen, Y., Karimi, K., 2016. Urban function connectivity: Characterisation of functional urban streets with social media check-in data. Cities 55, 9-21.

Song, J., Tong, X., Wang, L., Zhao, C., Prishchepov, A.V., 2019. Monitoring finer-scale population density in urban functional zones: A remote sensing data fusion approach. Landscape and urban planning 190, 103580.

Toole, J.L., Ulm, M., González, M.C., Bauer, D., 2012. Inferring land use from mobile phone activity, Proceedings of the ACM SIGKDD international workshop on urban computing, pp. 1-8.

Wang, Z., Ma, D., Sun, D., Zhang, J., 2021. Identification and analysis of urban functional area in Hangzhou based on OSM and POI data. PLoS one 16, e0251988.

Wang, Z., Xia, N., Zhao, X., Gao, X., Zhuang, S., Li, M., 2023. Evaluating Urban Vitality of Street Blocks Based on Multi-Source Geographic Big Data: A Case Study of Shenzhen. International Journal of Environmental Research and Public Health 20, 3821.

Yao, Y., Li, X., Liu, X., Liu, P., Liang, Z., Zhang, J., Mai, K., 2017. Sensing spatial distribution of urban land use by integrating points-of-interest and Google Word2Vec model. International Journal of Geographical Information Science 31, 825-848.

Yuan, G., Chen, Y., Sun, L., Lai, J., Li, T., Liu, Z., 2020. Recognition of functional areas based on call detail records and point of interest data. Journal of Advanced Transportation 2020, 1-16.

Yuill, R.S., 1971. The standard deviational ellipse; an updated tool for spatial description. Geografiska Annaler: Series B, Human Geography 53, 28-39.

Zeng, P., Wei, M., Liu, X., 2020. Investigating the spatiotemporal dynamics of urban vitality using bicycle-sharing data. Sustainability 12, 1714.

Zhang, X., Huang, R., Yang, Y., 2022. On the Landscape Activity Measure Coupling Ecological Index and Public Vitality Index of UGI: The Case Study of Zhongshan, China. Land 11, 1879.