Applying Spatial Techniques in Understanding Evolution and Accessibility of Cultural Facilities based on Multi-Source Data: A Case Study in Xiamen, China

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Limin Liang[1], Yue Wu[2], Jian Chu[3,*]

[1] School of Journalism and Communication, Xiamen University, 361005, Xiamen, China.
[2] School of Mathematical Sciences, Queen Mary University of London, London, UK.
[3] School of Arts and Media, Suqian University, Suqian, China.

*Corresponding Author: mrchujian@hotmail.com

ABSTRACT

Cultural facility is a kind of public facilities that can improve residents' education, ensure local cultural inheritance, and promote cultural exchanges. Well-planned construction of cultural facilities can promote sustainable development and avoid wasting resources. Xiamen, a coastal city with uneven development, is focused on this study. The time-space evolution of cultural facilities in Xiamen is studied by collecting total number of 34461 POI data, 229071 street data. With help of multi-source data and ArcGIS software, cultural facilities' distribution and accessibility are visualized and analysed as the standard deviation ellipse, kernel density analysis diagram and accessibility classification diagram. The results show that the construction of cultural facilities in Xiamen is mainly concentrated on the island and other coastal areas. The growth rate of construction was declined by 48.1% over the period. The unequal distribution of cultural facilities has increased over the past eight years. The accessibility of cultural facilities increased in 2016 and worsened in 2022. This is due to the government's emphasis on tourists and lack of attention to residents who lives in industrial areas. To improve equity of residents, strengthen on the construction of cultural facilities in Xiamen industrial zone is required.
Keywords: Cultural facilities; POI; Accessibility; China; ArcGIS.

INTRODUCTION

1.1 Cultural facilities

Cultural facilities generally refer to public facilities that educate and promote art and culture, including theatres, museums, and libraries (Jensen et al., 2020). In a broad sense, Spaces used to provide cultural exchange and learning can be referred to as cultural facilities (Zhang. J., 2022). For local communities, cultural facilities provide places to organize cultural events and promote local culture to tourists. For the local economy, cultural facilities can enhance the region's value, attract investors' interest, and obtain new estate projects. The quantity, quality,

and management of cultural facilities can directly affect residents' quality of life, improving regional competitiveness (Koval et al., 2018). Thus, cultural facilities are indispensable in city planning.

The development of cultural facilities in China began with the founding of New China in 1949. In 1953, the Ministry of Culture of China issued the *Instructions on Rectifying and Strengthening the Work of Cultural Centres and Stations*, clarifying the construction plan for cultural facilities for the first time. In 2021, the number of cultural and tourism units reached 324,600. On the 2nd of June 2021, the Ministry of Culture of China proposed that by 2025, the number of cultural facilities nationwide will reach 77,000, the annual service of cultural facilities will reach 4.8 billion, and the management of cultural facilities will be improved to ensure equality in education.

1.2 Development of cultural facilities

Research on cultural facilities originated in Europe. Due to the damage caused by World War II to cities, the massive demand for city construction led to the research on urban public facilities being mainly focused on the construction and management policies of cultural facilities. In terms of cultural services policies, Bonet et al. (2018) explored the evolution of cultural policy from the perspective that 'culture is the core of public services and public policies.' Sururi et al. (2022) explored a method for improving the level of cultural services from the ecological perspective, suggesting that the government should focus on ensuring cultural rights for low-income residents. The basic idea of these studies is that the services of cultural facilities can effectively enrich people's spirit and improve social equity. The influence of culture on a region is enormous (Zhang et al., 2022 & Chen et al., 2021). Since China's early development focused on industrial development and did not pay enough attention to cultural development, the function of cultural facilities has also been related with promoting *cultural confidence*. The 19th CPC Central Committee Congress in 2017 proposed strengthening cultural confidence and promoting social equity. Chinese scholars have begun to focus on improving cultural facilities and coverage of residents' living circles. However, previous studies are mainly qualitative studies based on the theory of public cultural services. Scientific planning is essential to achieve better coverage of cultural services. Ma et al. (2020) suggested that geospatial research can guide urban planning. By studying regional cultural facilities, space-time evolution can present distribution changes. The impact on social and economic development can be analysed by combining big data. In this way, the understanding of past spatial distribution can guide the future regional development and provide a reference for the development of other areas (Jiao et al., 2019).

1.3 Case of Xiamen

Due to the uneven distribution of development and resources, the construction of cultural facilities is unbalanced in different regions. Huang (2022) has pointed out that investment in cultural facilities in Fujian Province (China) is constantly increasing, but the government's enthusiasm has not met with an enthusiastic response from residents. One possible reason is the unreasonable site selection of cultural facilities. Therefore, studying the spatial distribution of existing cultural facilities is essential. Xiamen is a city in southern Fujian Province (China) with developed economy and it has a single island as the center of development. There is a large gap between the development of Island and the rest of Xiamen (Yang et al., 2022). By analyzing

the changes in the distribution of cultural facilities in Xiamen over time, suggestions for future construction in Xiamen can be provided.

LITERATURE REVIEW

2.1 Significance of cultural facilities

Cultural facilities are vital for residents' social networks. Cultural facilities such as libraries, cultural centres, and museums can group people, promoting information exchange and sharing. Hence cultural facilities are beneficial for reducing social issues such as social isolation and information cocoons. As mentioned in WCED (1987), development which meets the needs of current generations without compromising the ability of future generations to meet their own needs is defined as sustainable development. D'Alessandro et al. (2008) pointed out that sustainable development includes two components: improving the average living standard of people and promoting the fair distribution of social benefits. The construction of cultural facilities promotes sustainable development. From the perspective of society, the improvement of the infrastructure system can affect the residents' quality of life and better protect nature and assets (Uysa et al., 2010). Tvaronavičienė (2022) pointed out that regional cultural facilities can effectively improve residents' quality of life and social welfare, which is the basis of human capital and social capital appreciation. Sustainability is not a temporary or unique time. It is a continuous process of design resource development (WCED, 1987). Integration of economic development, social concerns, and environmental protection must be mutually reinforcing (Xie. Z., 2020). Quality of life is affected by many factors, including access to services, cost of living, and social participation. Alibegović and Slijepčević (2018) pointed out that the residents should actively participate in many public services. The complete construction of cultural facilities improves residents' social participation, cultural exchange, and cultural literacy.

2.2 Emergence of big data techniques

Existing research on cultural facilities mainly focuses on developing urban culture, formulating management policies, and exploring the multi-use development of cultural facilities. At present, research mainly focuses on three points: (1) Study of the spatial distribution of cultural facilities or cultural industries in specific cities; For example, Li et al. (2020) proposed that cultural facilities have strong centripetal agglomeration development characteristics using the method of data analysis. These studies remain at the theoretical level and use qualitative methods. (2) Study of utilization efficiency of urban cultural facilities or the relationship between supply and demand. For example, Chen et al. (2020) used questionnaires and other methods to study the local demand for and satisfaction with cultural facilities. This kind of research mainly used a sampling survey to discuss cultural facilities' progress from the economic development perspective. (3) Study of the planning and development strategy of cultural facilities. Chen et al. (2019) noticed the importance of cultural facilities in making cultural policies and used stakeholder workshops to analyse development policies. In these studies, taking individual behavioural characteristics as influencing factors or the starting point of planning is not well considered, lacking a comparison between the spatial distribution and individual behavioural characteristics. Cui et al. (2020) believed that residents with different education levels and consumption abilities have different needs for cultural facilities, these factors need to be

considered when planning facility constructions. Improving the accessibility of cultural facilities and residents' satisfaction constitutes the primary research purpose of this paper.

Hasan (2020) pointed out that with the development of computer and information technology, big data makes it easy to obtain massive data. The integration between subjects provides the possibility of quantitative analysis of imperceptible problems. In terms of facility distribution, big data enables large-scale quantitative analysis and design of urban, leading to the integration from neighbourhood to multiple scales of urban design (Rathore et al., 2016). In recent years, GIS, big data, and other technical methods have been gradually applied to the development strategy research of cultural facilities, which brings various advantages such as timeliness and accuracy. For example, Kong et al. (2022) conducted the subjective evaluation of Beijing's cultural facilities through the review data from online platforms and put forward corresponding suggestions on the planning and priorities of spatial scale agglomeration and spatial layout, classification, and spatial support. Yang et al. (2021) used Thiessen polygon analysis and buffer zone analysis to discover the relationship between historical legacies such as the Shanghai concession and the development of cultural facilities. Currently, studies on the spatial distribution of cultural facilities mainly focus on the balanced development of inland cities. The impact of uneven development of the coastal city on the distribution of cultural facilities is not clear. As a special economic zone of China, Xiamen has experienced rapid economic growth in recent years. The exploration of Xiamen based on big data can reflect how cultural facilities distributed and the accessibility problems.

METHODOLOGY

3.1 Research area

Xiamen is an economic and cultural centre in southern Fujian of, China. It is an island-based city. It comprises Xiamen Island (Huli District and Siming District), Jimei District, Tongan District, Xiangan District, Haicang District, and nearby islands, having a total coastline of 234 km. Xiamen Island is the area of Xiamen with the fastest urbanization rate and the most concentrated population. Due to its superior port resources, Xiamen became China's first urbanized coastal area. Rapid urbanization in the past 30 years has dramatically changed the ecosystem of Xiamen. The time-space evolution of cultural facilities in Xiamen is studied in our study by collecting total number of 34461 POI data, 229071 street data from open-accessed platforms.

3.2 Methodology

The development of analysing spatial characteristics is closely related to the development of digital technology. ArcGIS software was used to draw standard deviation ellipses and kernel density analysis. The standard deviation ellipse estimation method represents cultural facilities as an ellipse containing density and directionality. The standard deviation ellipse summarizes cultural facilities' centre, distribution, and orientation. Thus, overall spatial characteristics of cultural facilities can be observed. Kernel density estimation is an extension of the histogram. It shows the distribution of cultural facilities and reflects the change in agglomeration degree and agglomeration location of cultural facilities.

3.2.1 Standard deviation ellipse

Standard deviation ellipse (SDE) is a spatial statistical method quantitatively describe the spatial distribution characteristics of geographic elements by taking centre, major axis, minor axis, and azimuth as parameters (Zhang et al., 2022). The major axis (x) and minor axis (y) of SDE can reflect the directionality and density of elements, longer major axis indicates stronger directionality, shorter minor axis indicates more intensive spatial distribution (Hu et al., 2022). The azimuth angle of SDE can reflect the deviation degree of the main direction of distribution from the north. The formula Ellipse of standard deviation is as follows:

(1) Calculate the centre of SDE:

$$SDE_x = \sqrt{\frac{\sum_{i=1}^{E} (x_i - \bar{X})^2}{n}} SDE_y = \sqrt{\frac{\sum (y_i - \bar{Y})^2}{n}} \quad (1)$$

(2) Determine the direction of the major and minor axes:

$$\begin{aligned} \tan\theta &= \frac{A + B}{C} \\ A &= (\sum \tilde{x}_i^2 - \sum \tilde{y}_i^2) \\ B &= \sqrt{(\sum \tilde{x}_i^2 - \sum \tilde{y}_i^2)^2 + 4(\sum \tilde{x}_i \tilde{y}_i)^2} \\ C &= 2\sum \tilde{x}_i \tilde{y}_i \end{aligned} \quad (2)$$

(3) Determine the rotation Angle:

$$\begin{aligned} \sigma_m &= \sqrt{2} \sqrt{\frac{\sum (\tilde{x}_i^2 \cos\theta - \tilde{y}_i^2 \sin\theta)}{n}} \\ \sigma_p &= \sqrt{2} \sqrt{\frac{\sum (\tilde{x}_t^2 \sin\theta - \tilde{y}_i^2 \cos\theta)^2}{n}} \end{aligned} \quad (3)$$

Where x_i, y_i is the coordinates (longitude and latitude), $\bar{Y}$ and $\bar{X}$ represent weighted mean centre, $\tilde{\boldsymbol{x}}_i$, $\tilde{\boldsymbol{y}}_i$ is difference between mean center and x_i, y_i.

3.2.2 Kernel density estimation

Kernel density estimation (KDE) is widely used in GIS analysis. By calculating the spatial distribution of geographical elements, the spatial agglomeration state can be visually reflected. Extends the discrete distribution of points to a continuous distribution, takes the distance of points as the weight to generate a continuous density surface, kernel density value is calculated. The formula Kernel density estimation is as follows:

$$f(x) = \frac{1}{nh}\sum_{i=1}^{n} K\left(\frac{x - x_i}{h}\right) \quad (4)$$

Where: h is the search radius; n is the number of cultural facilities in the circle; K is the kernel function representing the weight of space. x_i denotes the position of the cultural facility within the circle with the center as x, radius as h.

3.2.3 Facility Service area

Accessibility in spatial analysis generally refers to the difficulty for residents to reach a specific location. Specifically, accessibility is quantitatively expressed by residents' desire and ability to reach a service facility by overcoming impendence such as distance, travel time, and cost. Due to the necessity of cultural facilities in daily life, residents usually visit the cultural facilities closest to their place (Ko et al., 2018). Xiamen's cultural facilities were classified according to the average travel time from resident communities and streets proportion. ArcGIS software was used to calculate the accessibility of public facilities in the residential area. The average accessibility and the proportion of the number of residential communities within 20 minutes to the total number of residential communities were used to describe the spatial pattern of accessibility of cultural facilities in Xiamen. The corresponding colour blocks of average accessibility were filled into corresponding areas to depict the spatial pattern of accessibility.

RESULTS

4.1 Spatial distribution analysis

The SDE is drawn based on the Xiamen city map and Point of Interest (POI) data to analyse the spatial distribution of cultural facilities in different years. In general, the centre of Xiamen cultural facilities' SDE is located in the middle of Huli District. The major axis points north and south. The proportion between the major and minor axes indicates that Xiamen's cultural facilities are intensively distributed. Comparing the SDE of cultural facilities in 2012 and 2016 (See Figure 1). The centre of gravity of the SDE moved 1.3km to the south, and the difference between the major axis and the major axis decreased, while the minor axis remained unchanged. This indicates that the distribution of cultural facilities in Xiamen is generally closer to the south, and the directionality of cultural facilities is reduced. The construction of Xiamen's cultural facilities was mainly concentrated in the southern part of Xiamen over four years. The centre and axis of the SDE of 2016 and 2022 are almost the same, indicating that the construction proportion and distribution of cultural facilities remain unchanged.

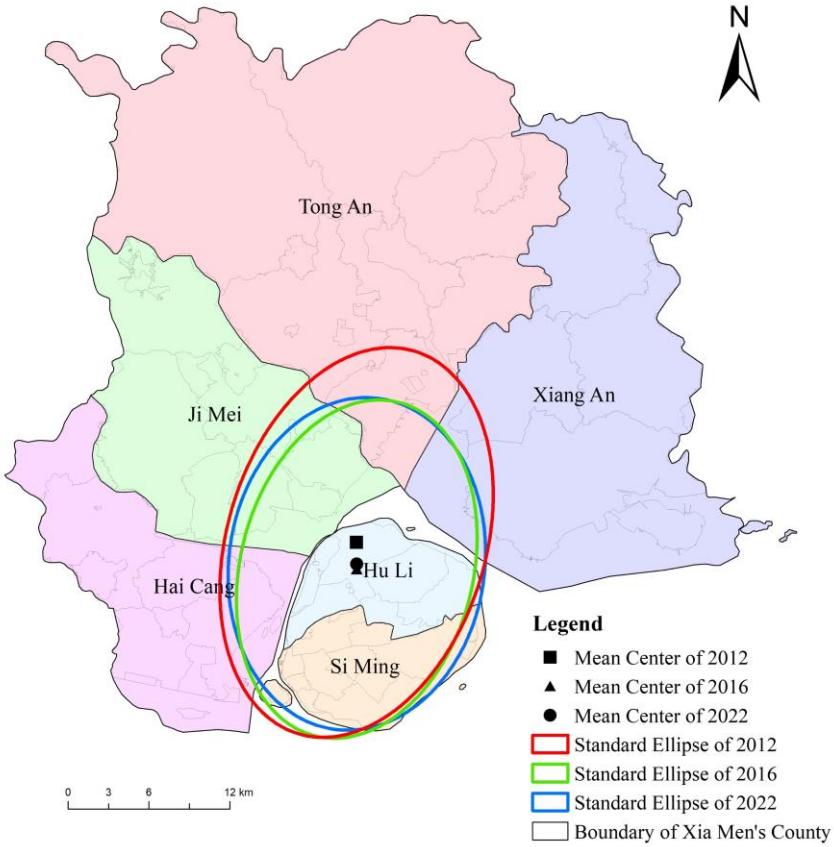
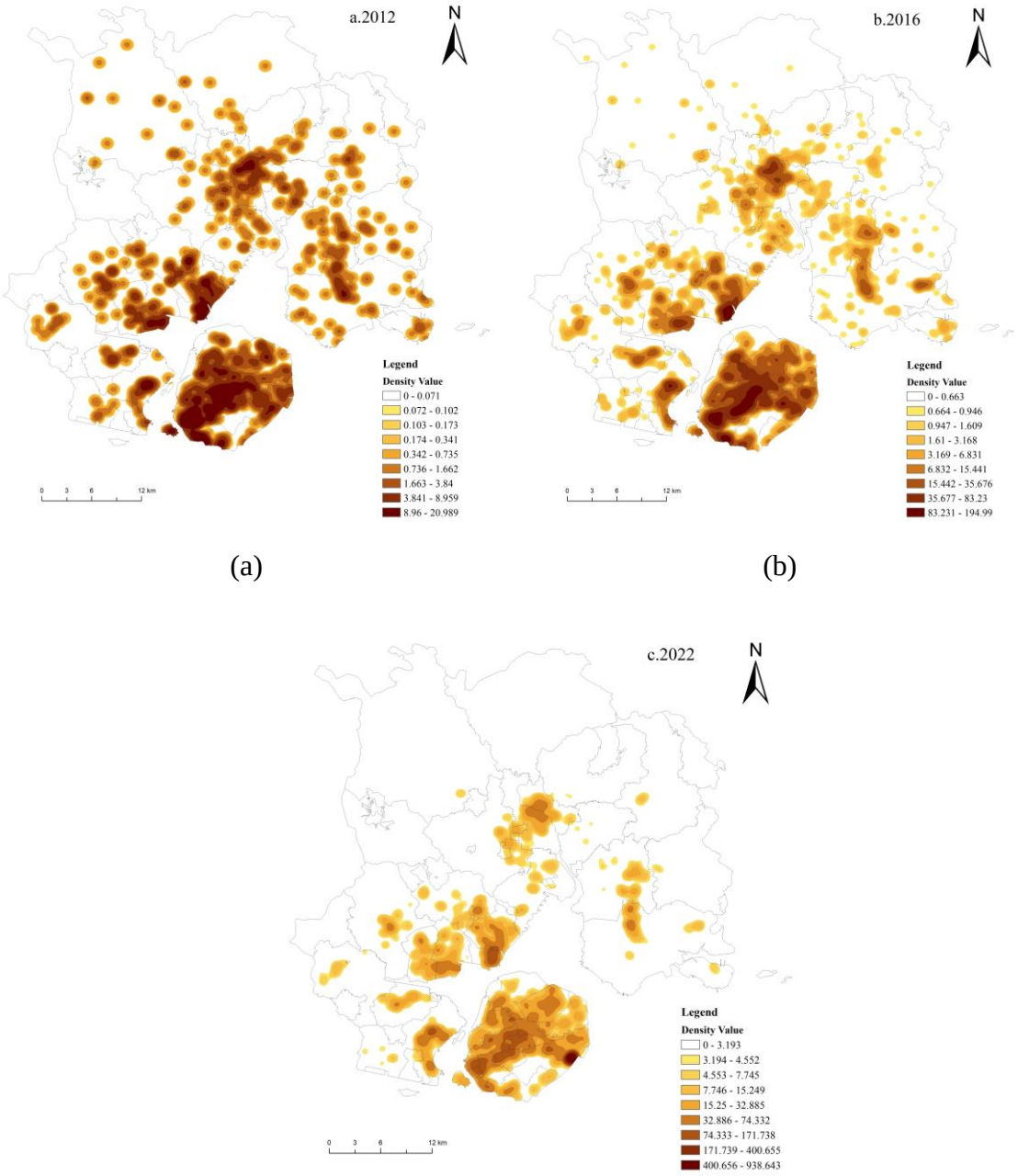


Figure 1. Standard deviation ellipse of cultural facilities.

4.2 Agglomeration analysis

The kernel density analysis of cultural facilities shows that the spatial distribution of cultural facilities in Xiamen is highly concentrated on Xiamen Island. The concentration of cultural facilities decreases with the rise of latitude (See Figure 2). In general, the distribution of cultural facilities in 2012 was relatively average. There was no significant difference between the Island, coastal areas, and the rest part of Xiamen. In 2016, there was a significant between the Island, coastal areas, and the rest of Xiamen. Radiation distribution cantered on Xiamen Island was observed. In the far south of Xiamen, Cultural facilities are widely scattered. In 2022, the gap between Xiamen Island and the outside widened. In 2012, the highest kernel density value was 20.989, and the highest value in 2016 was 194.99, with a difference of 9.29 times. The highest kernel density value in 2022 is 938.643. The difference between 2016 and 2022 was 4.81 times. The percentage growth declined by about 48.1% over the period. The construction speed of cultural facilities in Xiamen is slowing down by year. Furthermore, the dark blocks in 2012 were distributed evenly, while the dark blocks in 2022 were concentrated in Siming District. Thus, the construction of cultural facilities in Xiamen is slowing down yearly, while the imbalance between the construction inside and outside the Island is increasing. Apart from Xiamen Island. Cultural facilities in South Jimei, central Tongan, and central Xiangan are all clustered to a certain extent. In 2022, an explosive cluster appeared in the east of Xiamen's

Siming district, presumed to be caused by the development of new tourist attractions. To ensure residents' equity, the corresponding government should increase the construction of cultural facilities outside the Island. Cultural facilities are not only a tool to attract tourists, but it is also important to local residents.



(a) (b)

(c)

Figure 2. Kernel density of cultural facility.

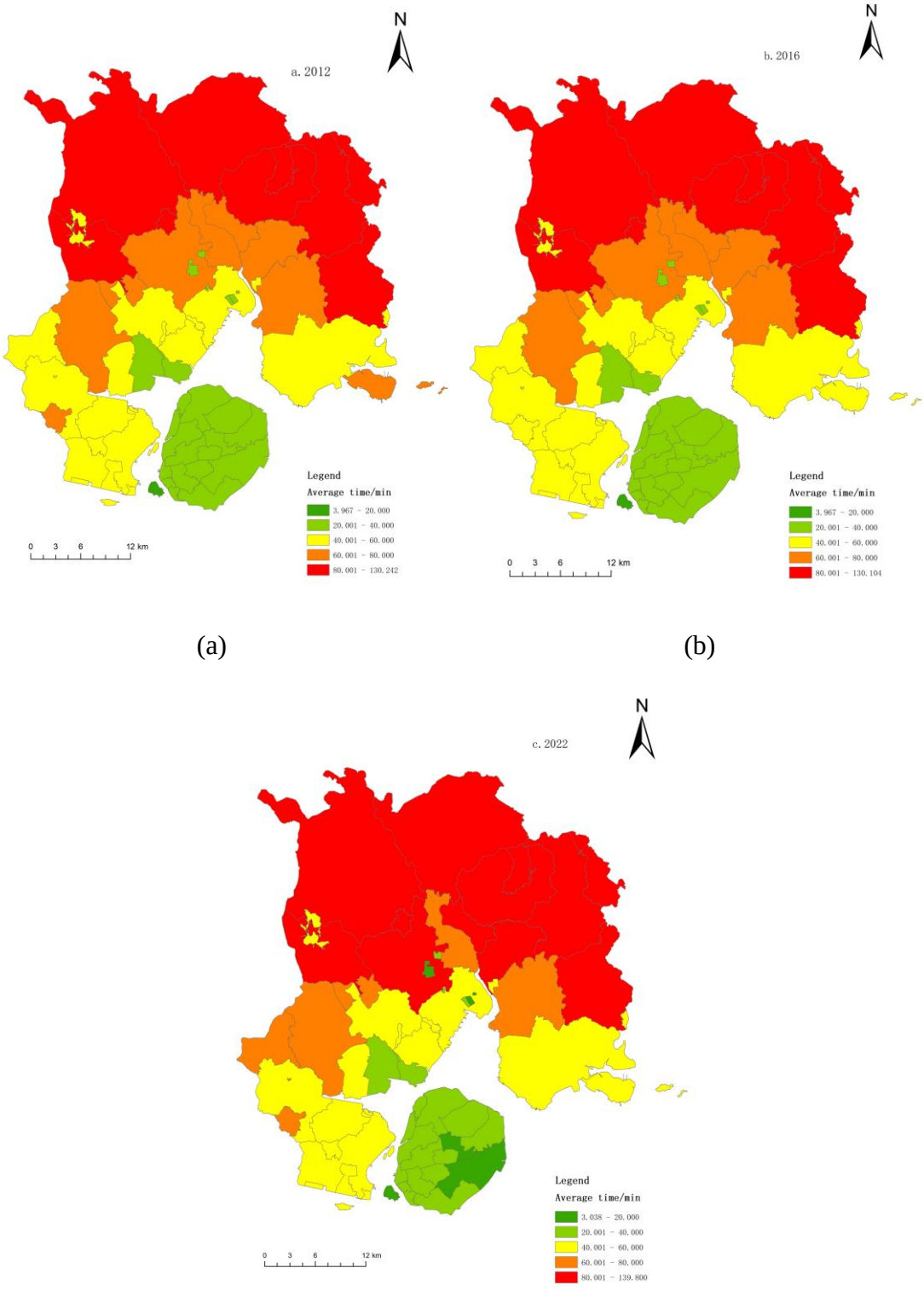
4.3 Accessibility analysis

Combining the transportation data, residential, and cultural facilities' POI of Xiamen, accessibility in 2012, 2016, and 2022 was calculated. Accessibility was classified by travel time, with every 20 minutes as a step. We defined a travel time of 0 - 20 minutes as excellent accessibility, 20 - 40 as good accessibility, 40-60 minutes as average accessibility, 60-80 minutes as poor accessibility, and an average travel time of 80+ minutes as very poor accessibility. From the map of accessibility of cultural facilities each year (see Figure 3), it can be observed that there is no significant change in accessibility between 2012 and 2016. The accessibility has changed from poor to Average in some areas, such as the east of Xiangan District. However, the accessibility in 2022 is worsen compared to 2016. It can be observed that the accessibility of central Xiamen has changed from poor to very poor. This may be due to local industrialization. The accessibility of eastern Siming District improved from good to excellent, and local tourism development might cause it. Overall, the accessibility of cultural facilities on Xiamen Island is consistently maintained at the level of "good," and the accessibility of cultural facilities decreases with the increased distance from Xiamen Island. The accessibility of the northernmost part has been maintained at a very poor level for eight years, while the southern part of Jimei District has maintained good accessibility. This may be due to the distribution of local industries. The primary industries in the north of Xiamen are clothing and food, while the main industries in the south of Jimei are education. After eight years of development, the overall accessibility of Xiamen has not been significantly improved and may even be reduced. The relevant government should take note of this situation and shift the development focus to poor accessibility areas with high populations, such as the central Xiangan District.

CONCLUSION

Taking Xiamen as the research object, this paper uses POI data and the ArcGIS tool to study the spatial distribution changes of cultural facilities in Xiamen. The standard deviation ellipse, kernel density, and accessibility classification were calculated and visualized. The study aims to help sustainable development, ensure fairness in the distribution of cultural resources in Xiamen and provide development references for coastal cities. The results showed that the spatial distribution of cultural facilities in Xiamen did not change significantly over eight years. Cultural facilities are mainly concentrated in Xiamen Island (Siming District, Huli District), the south of Siming District, and the middle of Tongan District. The construction speed of cultural facilities in Xiamen is slowing down yearly, but the gap between Xiamen Island and outside the island is increasing. The unbalanced development between the island and outside is increasing, and this situation has not been paid attention to by relevant departments. The accessibility and distribution of cultural facilities in Xiamen follow the same trend. The areas with high accessibility are mainly located south of Jimei district and Xiamen Island. Accessibility to cultural facilities increased in 2016 but worsened in 2022. As a coastal city, the primary industry on Xiamen Island is tourism, while the main industry outside Xiamen is the light industry and clothing industry. Although there are more residents on Xiamen Island, the construction of cultural facilities on Xiamen Island is nearing saturation, while the construction outside Xiamen Island is insufficient. To ensure cultural equity for the residents and promote

economic development, the relevant government should focus on developing the southernmost part of Xiamen. Due to the limited data, only three years were analyzed in this paper, and the cultural facilities were not classified in detail. Further exploring of specific cultural facility's spatial layout will be focused on in the future.



(a) (b)

(c)

Figure 3. Accessibility classification of cultural facilities.

REFERENCES

Jensen, A. & Bonde, L.O. 2020. An arts on prescription programme: perspectives of the cultural institutions. Community Mental Health Journal.56 (8) 1473-1479.

Zhang, J. 2022. Application of prediction model using parallel computing in music cultural facilities. Scientific Programming.2022 (8400206) 1-9.

Koval, V., Polyezhayev, Y. & Bezkhlibna, A. 2018. Communicative competences in enhancing of regional competitiveness in the labour market. Baltic Journal of Economic Studies.4 (5) 105-113.

Bonet, L. & Négrier, E. 2018. The participative turn in cultural policy: Paradigms, models, contexts. Poetics.66, 64-73.

Ma, Y., Jiang, Y. & Swallow, S. 2020. China's sponge city development for urban water resilience and sustainability: a policy discussion. Science of the Total Environment.729, 139078.

Jiao, L. & Jiang, H. L. 2019. Metal-organic-framework-based single-atom catalysts for energy applications. Chem.5 (4), 786-804.

Huang, Y. & Lin, J. 2021. The cultivation of undergraduates majoring in cultural industry management from a regional perspective based on a case study of Southern Fujian. Adult and Higher Education. 3 (1) 85-94.

Ji, X., Wang, K., Ji, T., Zhang, Y. & Wang, K. 2020. Coupling analysis of urban land use benefits: A case study of Xiamen city. Land.9 (5) 155.

WCED, S.W.S. 1987. World commission on environment and development. Our common future.17 (1) 1-91.

D'Alessandro, S., Cieplinski, A., Distefano, T. & Dittmer, K. 2020. Feasible alternatives to green growth. Nature Sustainability.3 (4) 329-335.

Uysal, M. & Sirgy, M. J. 2019. Quality-of-life indicators as performance measures. Annals of Tourism Research.76, 291-300.

Tvaronavičienė, M., Mazur, N., Mishchuk, H. & Bilan, Y. 2022. Quality of life of the youth: assessment methodology development and empirical study in human capital management. Economic Research-Ekonomska Istraživanja.35 (1) 1088-1105.

Xie, Z. 2020. China's historical evolution of environmental protection along with the forty years' reform and opening-up. Environmental Science and Ecotechnology.1 (100001) 1-8.

Alibegović, D.J. & Slijepčević, S. 2018. Attitudes towards citizen participation in the local decision-making process: A comparative analysis. Društvena istraživanja.27 (1) 155-157.

Li, L., Lu, L., Xu, Y. & Sun, X. 2020. The spatiotemporal evolution and influencing factors of hotel industry in the metropolitan area: An empirical study based on China. PloS one.15 (5) e0231438.

Chen, S., Wang, Y., Ni, Z., Zhang, X. & Xia, B. 2020 Benefits of the ecosystem services provided by urban green infrastructures: Differences between perception and measurements. Urban Forestry & Urban Greening.54 126774.

Cheng, X., Van Damme, S., Li, L. & Uyttenhove, P. 2019. Evaluation of cultural ecosystem services: A review of methods. Ecosystem services.37 100925.

Cui, X., Ma, L., Tao, T., & Zhang, W. 2022. Do the supply of and demand for rural public service facilities match? Assessment based on the perspective of rural residents. Sustainable Cities

and Society.82 103905.

Wong, Z. S., Zhou, J. & Zhang, Q. 2019. Artificial intelligence for infectious disease big data analytics. Infection, disease & health.24 (1) 44-48.

Rathore, M.M., Ahmad, A., Paul, A., & Rho, S. 2016. Urban planning and building smart cities based on the internet of things using big data analytics. Computer networks.101 63-80.

Kong, L., Liu, Z., Pan, X., Wang, Y., Guo, X. & Wu, J. 2022. How do different types and landscape attributes of urban parks affect visitors' positive emotions? Landscape and Urban Planning. 226, 104482.

Yang, H., Li, C., Li, X., Huo, J., Wen, Y., Parks, E. & Liu, Y. 2021. Effects of coverage area treatment, spatial analysis unit, and regression model on the results of station-level demand modeling of urban rail transit. Journal of Advanced Transportation.2021 (7345807) 1-10.

Zhang, X., Zhang, B., Yao, Y., Wang, J., Yu, F., Liu, J. & Li, J. 2022. Dynamics and climatic drivers of evergreen vegetation in the Qinling-Daba Mountains of China. Ecological Indicators.136, 108625.

Hu, J., Liang, J., Fang, J., He, H. & Chen, F. 2022. How do industrial land price and environmental regulations affect spatiotemporal variations of pollution-intensive industries? Regional analysis in China. Journal of Cleaner Production.333, 130035.

Ko, H. & Son, Y. 2018. Perceptions of cultural ecosystem services in urban green spaces: A case study in Gwacheon, Republic of Korea. Ecological indicators, 91, 299-306.

Sururi, A., Rusli, B., Widianingsih, I. & Ismanto, S.U. 2022. Housing policy for low-income communities in indonesia and its reforms: an overview. Public policy and administration.21 (1) 158-174.

Yang, J., Ma, H. & Weng, L. 2022. Transformation of rural space under the impact of tourism: the case of Xiamen, China. Land.11 (6) 928.

Hasan, M., Popp, J. & Oláh, J. 2020. Current landscape and influence of big data on finance. Journal of Big Data.7 (1) 1-17.

Chen, M. & Zhang, W.H. 2021. Purchase intention for hydrogen automobile among Chinese citizens: The influence of environmental concern and perceived social value. International Journal of Hydrogen Energy.46 (34) 18000-18010.

Zhang, W.H., Chou, L.C. & Chen, M. 2022. Consumer perception and use intention for household distributed photovoltaic systems. Sustainable Energy Technologies and Assessments.51 101895.