

Contents lists available at [ScienceDirect](https://www.sciencedirect.com)

International Journal of Law, Crime and Justice

journal homepage: www.elsevier.com/locate/ijlcrj

Position Paper

Spatio-temporal characteristics of sexual crime and influencing factors of commercial service facilities: A case study of Haining City, China

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ARTICLE INFO

Keywords:

Sexual crime
Spatio-temporal pattern
Commercial service facilities
Geodetector
Haining city

ABSTRACT

This study aims to reveal the spatial and temporal distribution characteristics of sexual crimes in Haining city and the spatial relationship between them and urban commercial service facilities, so as to provide decision-making reference for the prevention and treatment of sexual crimes. Based on the data of 311 sexual crimes in the case management system of public security organs and the POI data of urban functional facilities in the community policing system, using methods such as nearest neighbor index, nuclear density estimation and Geodetector, the data from January 2014 to September 2021 are analyzed. The formation of the spatial pattern of sexual crimes is the result of the multiple factors, especially the distribution of KTVs, Internet cafes, hotels and other commercial service facilities. Sexual crimes will increase significantly in areas with mixed facilities. We put forward countermeasures and suggestions for the effective development of sexual crime rectification work in Haining.

1. Introduction

Sexual crime is a global problem. A woman's lifetime risk of being raped or having been raped is as high as 20%, and more than 90% of sexual assault victims are women (Welch and Mason, 2007). Sexual crime, in contrast to property crime or even physical assault, is considered a vicious crime of self-aggression against the victim (Petrunik, 2003). With the popularity of the Time's Up movement, there is growing public awareness of sexual harassment and assault and their impact on women's health (Bernat and Pelletier, 2018). Sexual crimes can cause serious physical and mental damage to victims, and studies have shown that women with a history of sexual assault have significantly higher rates of clinically significant depressive symptoms, anxiety and poor sleep than women without a history of sexual assault (Thurston et al., 2019). Therefore, it is urgent to study sex crime in depth in order to prevent crime better.

Some scholars have carried out relevant studies from the perspectives of offenders and victims. Mustaine and Tewksbury evaluated whether the characteristics of the residential community of sex offenders (RSO) and race affect the location of these RSO (Mustaine and Tewksbury, 2008). Beauregard and Leclerc investigated the decision-making process of 69 serial sex offenders who committed crimes

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<https://doi.org/10.1016/j.ijlcrj.2023.100647>

Received 17 August 2023; Received in revised form 28 November 2023; Accepted 18 December 2023

Available online 23 December 2023

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against unknown victims based on rational choice method. Semi-structured interviews were conducted with offenders to determine the rationale behind their behaviour in the pre-crime, criminality and post-criminality stages (Beauregard and Leclerc, 2007). Williams analyzed the relationship between the victim and the rapist, as well as the context of the attack, the threat and use of force, the degree of injury, and the need for medical treatment (Williams, 1984). As for sexual crimes against adolescents and children (Brayley et al., 2011; Ward and Keenan, 1999), Woodhams illustrates some of the differences between young people who commit sexual crimes and general offenders in areas such as atypical sexual interests, pornography use, and early childhood sexual victimization (Woodhams, 2009). Mustaine et al. studied the utility of social disintegration theory as an explanation for child sexual abuse (Mustaine et al., 2014). Tewksbury et al. examined the utility of social disintegration theory in identifying community characteristics that are differently associated with general and child-specific sexual crime rates (Tewksbury et al., 2010).

According to scholars' research on human mobility, daily activities differ significantly between people, but individual activity habits show a strong daily and weekly repetition rhythm (Gonzalez et al., 2008; Pappalardo et al., 2015; Song et al., 2010). This pattern of repetition, in turn, affects crime (Cohen and Felson, 1979). Anderson (Anderson, 1989) and Gabor and Gottheil (Gabor and Gottheil, 1984) pointed out that the incidence rate of sexual crimes in summer was much higher than that in winter. Warren et al. (1998) found that rapists' farthest commutes to crime occurred on weekends. Warren et al. (1998) found that almost half of the rapes occurred in the evening and night, and two thirds of the rapes occurred in the early morning, and then studied the fluctuation of the overall crime rate. Ceccato analyzed the change of the role of environment on the occurrence of rape over time and space, which is of great significance for research and safety intervention (Ceccato, 2014). Balemba and Beauregard analyzed the complexity of sexual crime events and their situational components (Balemba and Beauregard, 2013). Woodhams et al. addressed research disparities by investigating the timing and geographic proximity of crimes committed by 402 serial stranger sex offenders in the United Kingdom (Woodhams et al., 2021). Samantha and Eric analyzed sexual crimes across space-time (Balemba and Beauregard, 2013). An Jun made a statistical analysis of the crime situation of Shanghai from 2014 to 2020, and conducted a comprehensive analysis of various crimes including sexual crimes from the perspective of space-time (An, 2022). Ashley and Eric applied rational choice theory to explore the impact of environment and criminal behavior on the outcome of serial sexual crimes from the perspectives of time, space and other factors (Hewitt and Beauregard, 2014). Ashley studied the spatio-temporal characteristics of sexual crimes from the perspective of crime pattern theory and social disorganization theory (Hewitt et al., 2018). Three measures of spatial clustering, kernel density analyses, and a spatial point pattern test are used to analyze the spatial distribution (Hewitt, 2021). Subham and Indrajit used geographic information systems and spatial analysis techniques to examine the geographical distribution of sexual crimes in West Bengal. Understanding the spatio-temporal dynamics of sexual crimes is essential for policy development, prevention strategies and resource allocation (Roy and Chowdhury, 2023). At present, there are few studies on sexual crimes from the perspective of spatial and temporal distribution. Studying the spatial and temporal distribution of sexual crimes is helpful to prevent it, and can provides certain countermeasures and suggestions.

Scholars have did a lot of research in studying sexual crime theory, such as routine activity theory (Belknap, 1987; Maume Jr, 1989), social disorganization theory (Sutherland, 1943), theories of rape (Polaschek and Ward, 2002), five core implicit theory opportunity theory (Polaschek and Gannon, 2004; Ward and Keenan, 1999), opportunity theory (Warr, 1988), six models of rape (Gentry, 1989), crime script theory methods (Beauregard et al., 2007a; Brayley et al., 2011; Cornish, 1994; Dehghanniri and Borrión, 2021; Deslauriers-Varin and Beauregard, 2010) and etc. Researchers examined the utility of social disorganization theory in identifying community characteristics that are associated with different rates of sexual crime in general and against children (Tewksbury et al., 2010). The social disorganization theory had a good explanation for adult sexual crimes. Maume Jr. used the routine activity theory to construct two crime opportunity indexes and studied the impact of inequality and ethnic composition on rape (Maume Jr, 1989). Ward and his colleagues described five core implicit theories and discussed its relationship to cognitive distortion (Ward and Keenan, 1999). At present, there were few studies combining routine activity theory, crime pattern theory and sexual crimes. This paper analyzed temporal and spatial characteristics of sexual crimes by combining routine activity theory, crime pattern theory and other criminological theories, and then put forward suggestions on sexual crime prevention. In terms of methods and models of sexual crimes, scholars have carried out a lot of research work (Beauregard et al., 2007b; Nobles et al., 2012). Santtila et al. believe that the crimes of different criminals are distinguishable in terms of the differences between the crimes of different criminals and the consistency within the crimes of the same offender (Santtila et al., 2005). Beauregard et al. explored the relationship between the characteristics of the offender, the variables of the mode of crime and the walking distance of the sex offender (Beauregard et al., 2005). Polaschek and Gannon constructed and outlined five core implicational theories (Polaschek and Gannon, 2004). Petrunik compared the different trajectory taken by community conservation in the United States and Canada, and offered an explanation for the relatively slow and cautious approach taken by the Canadian federal government (Petrunik, 2003). Canter and Larkin took 45 British male sex offenders as research objects and established a model of spatial activity of individual sex offenders, which supported the value of the "egocentric" theory in the life of criminals and provided potential applicability for solving crimes (Canter and Larkin, 2008). Deslauriers-Varin and Beauregard discussed the empirical and methodological significance of the study of behavioral consistency as well as its practical significance for the connection between police investigation and crime (Deslauriers-Varin and Beauregard, 2013). Winter et al. compared a more theory-based multidimensional behavior approach with a more practical multivariate behavior approach, and compared their accuracy in associating a sample of serial sexual assault with a single sexual assault in Britain (Winter et al., 2013). From the perspective of research methods and models, there were few studies on sexual crimes by geographical model methods. This study analyzed spatial differentiation characteristics and explanatory power of the influencing factors of sexual crimes from the perspective of geography, and also discussed factors affecting the built environment of sexual crimes. It did enrich the geographical method and empirical study of sexual crime.

In terms of geospatial and sexual crimes, a large number of scholars began to recognize the importance of microgeographic units in the study of sexual crimes (Bursik Jr and Grasmick, 1993; Sherman and Weisburd, 1995) and began to study crime from the perspective

of geographic space. On the urban scale, studies showed that sexual crimes mostly occur in buildings, fields, streets, paths, parks, and etc.(Belknap, 1987; Canter and Larkin, 1993; Deslauriers-Varin and Beaugard, 2010), which were some of the more isolated, unguarded outdoor sites (Ceccato, 2014) or where bars and restaurants gathered(Cohen and Felson, 1979; Hewitt et al., 2018; Rosay and Langworthy, 2003). On the community scale, more sexual crimes occurred in communities with social disorder(Maume Jr, 1989; Pyle et al., 1974; Tewksbury et al., 2010), and women were often more at risk in the home than outdoors, because women were more vulnerable to acquaintances(Dymén and Ceccato, 2012; Tewksbury et al., 2010); Socia proved that housing policies such as residence restrictions can help mitigate the risk of certain types of sexual offences(Socia, 2013). Lundrigan et al. studied the crime patterns of 76 serial sex offenders in New Zealand to determine the extent to which offenders exhibit geographic consistency in choosing their crime locations (Lundrigan et al., 2010). Hewitt and Beaugard used the perspective of rational choice to explore the impact of environment and criminal behavior on the outcome of serial sexual crimes (Hewitt and Beaugard, 2014). Stangeland's documented analysis of enhanced geographic profiles based on theories about the zones of consciousness, activity spaces, and buffer zones of serial offenders (Stangeland, 2005). Beaugard and Rebocho analyzed that rapists in Canada and Portugal showed different patterns of target selection, but their geographic decisions were consistent with their circumstances (Beaugard et al., 2010). It can be seen that there are some studies on different scales of geospatial scholars, but there is a lack of characteristics of research crimes from the perspective of commercial service facilities. Based on criminological theories, many scholars have studied the impact of different types of urban facilities on criminal behavior, such as schools, bars, shopping centers, hotels, hotels and etc(Bromley and Nelson, 2002). Roncek analyzed the impact of public middle schools and bars on criminal behavior(Roncek and Faggiani, 1985; Roncek and Maier, 1991). Hope analyzed the relationship between public space, entertainment facilities, bus interchange points, shopping malls, shops and other urban facilities and criminal behavior(Hope, 1997). Commercial service facilities were dense areas deployed with urban facilities and crowd which were closely related to sexual crimes(Bai, 2014; Jiang, 2018), increasing the possibility of crimes.

In terms of influencing factors and correlation of sexual crimes, many scholars have conducted research and discussion(Hewitt et al., 2012; Rosay and Langworthy, 2003). Ceccato et al. used VISUAL-TimePacTS, geographic information systems, and conditional logistic regression to determine the location, context, and social interaction factors associated with the occurrence of rape (Ceccato et al., 2020). Rebocho and Silva conducted an empirical study on the geographical characteristics of sexual crimes, hunting behavior and hunting process of criminals, geographical decision-making in target selection, and the influence of routine activities and types of criminals on target selection (Rebocho and Silva, 2014). Using data from Detroit, Michigan, Lersch and Har used optimized hotspot analysis and risk terrain modeling (RTM) to identify key spatial factors that limit the occurrence of sexual assault before, during, and after the COVID-19 epidemic (Lersch and Hart, 2023). Hewitt et al. used socio-demographic factors, land use, specific sexual crime attraction factors and ecological variables to predict areas with high incidence of sexual crimes in big cities (Hewitt et al., 2018). Hewitt et al. first attempted to use GEE to predict factors related to encounter and location of release in serial rape(Hewitt et al., 2012). Deslauriers-Varin and Beaugard discussed the theoretical relevance of these target selection scripts and their practical implications for situational crime prevention strategies (Deslauriers-Varin and Beaugard, 2010). Warren et al. studied the relationship between demographics, crime scene and crime history variables and the distance traveled by serial rapists to commit crimes (Warren et al., 1998). Socia found that RSO clustering was positively associated with a modest increase in arrest rates for recidivism sex crimes, but the results were significant only for adult victim sex crimes and certain types of RSO clustering(Socia, 2013). These studies are expected to provide theoretical support for crime prevention through the analysis of influencing factors and related predictions.

It can be seen that many scholars have explored the relationship between the occurrence of sexual crimes and geographical space, and carried out research work from different scales of geographical space such as city scale, community scale and geographical environment. The discussion of different scale space had important guiding significance for analysis of characteristics of sexual crimes. Urban business districts were high incidence areas of sexual crimes(Ceccato, 2014). However, presently there was a lack of research on characteristics of sexual crime from the perspective of commercial service facilities. Most of studies were carried out separately from the perspective of space-time, but there were relatively few studies from both time and space. There were studies about sexual crime theory, but less analysis on sexual crime combined with routine activity theory and the crime pattern theory. Presently, among research on influencing factors of sexual crime from the perspective of geography, there was a lack of study on characteristics of sexual crime from the perspective of commercial service facilities. In general, the existing studies on sexual crimes mainly focus on the influence of various influencing factors on the distribution of crime points(Balemba and Beaugard, 2013; Hewitt et al., 2012), and rarely analyze the interaction among influencing factors. And there is often a lack of research on the urban environment of sexual crimes, such as hotels, entertainment places. Significantly different from other criminal crimes, the victims of sexual crimes are mostly women, which has a serious negative impact on the atmosphere of life and cultural environment(Bernat and Pelletier, 2018). Moreover, sexual crimes have high requirements for the crime environment and are greatly affected by commercial service facilities (Jiang, 2018; Muldoon et al., 2019). Whether the spatial distribution of sexual crimes is related to specific factors of commercial service facilities is a typical problem of criminal geography, which deserves further study.

Taking Haining City, China as the research area, this study used spatial analysis methods such as nearest neighbor index, standard deviation ellipse, nuclear density estimation, and geographic detector to study the spatio-temporal distribution characteristics of 311 sexual crimes in Haining urban area and the spatial relationship between commercial service facilities and sexual crimes. Specifically, this study aims to reveal the spatial and temporal distribution characteristics of sexual crimes in Haining city and the spatial relationship between them and urban commercial service facilities, so as to provide decision-making reference for the prevention and treatment of sexual crimes.

2. Study area and data

2.1. Study area

Haining is located in Jiaying City in northern Zhejiang Province, with jurisdiction over 4 subdistricts and 8 towns, covering an area of 863 square kilometers. According to the seventh national census, the city's permanent resident population is 1,076,000, with males accounting for 52.66%. In 2020, the GDP of Haining reached 103.078 billion yuan, ranking 17th in the list of the top 100 counties in China. The tertiary industry is developed. There are many commercial and entertainment places such as hotels, KTV, foot bath and massage, beauty salon and so on. So, the sexual crimes frequently occur, which can be supported by sufficient data. As the suburbs of the city, which mainly consist of villages, farmlands and scenic spots, are sparsely populated and less criminal, only the central urban area consisting of Xiashi Sub-district, Haizhou sub-district, Haichang sub-district and Maqiao sub-district is selected as the study area, with a total area of 243 square kilometers, accounting for 28% of the total area of Haining City.

2.2. Data

Sexual crime is a violation of the criminal law by intentionally violating the sexual rights or sexual health of another person or by impairing social decency related to "sex" (Wu, JP, 1998). This study mainly focuses on the indecent assault and rape of women. The data on sexual crimes, including rape and indecent assault crimes, was provided by the Public Security Bureau of Haining City, covering a total of 311 cases from January 2014 to September 2021. The data fields include the time, type and longitude and latitude coordinates of sexual crimes. The data of commercial service facilities was also provided by the Public Security Bureau of Haining City, which recorded 46 types of places collected by the public security police, such as hotels, KTV, beauty salons, teahouses, foot baths, chess and card rooms, bars, Internet cafes, baths, etc. which are managed or focused on by the Public Security Bureau of Haining City, totaling 31,634. Include facility name, type, and latitude and longitude coordinates. Since various places in the central urban area of Haining were relatively stable, and no large epidemic incidents occurred in Haining since 2020, so there was little impact on the operation of various facilities. That was the reason that study chose data of various places in Haining city obtained from the community policing system in 2021. The time of acquisition was October 11, 2021.

3. Methodology

3.1. Nearest neighbor index

Nearest neighbor index (NNI) is to calculate the average distance between two points and compare it with the average distance in the random distribution mode to analyze the degree of deviation from the random distribution (Chengli et al., 2020; Jia et al., 2019). The calculation formula is:

$$NNI = \frac{\sum_{i=1}^N \frac{\min d_{ij}}{N}}{\frac{1}{2} \sqrt{S/N}}, \quad (1)$$

NNI is the nearest neighbor index, i and j are respectively the location of any two sexual crimes. The $\min d_{ij}$ is the distance between any crime place and the nearest crime place. The N is the total number of cases, and the S is the area of the sample. The numerator is the average observed distance between occurrence sites, and the denominator is the expected average distance between occurrence sites. When $NNI < 1$, it indicates that the sexual crimes present spatial agglomeration distribution. On the contrary, if $NNI > 1$, it shows discrete distribution.

3.2. Kernel density estimation

Kernel density estimation is one of the most widely used nonparametric techniques in data analysis. By constructing a continuous probability density function, we can obtain a smooth sample distribution, measure the spatial density change, and explore the hot spot distribution of sexual crimes (Wenhao and Tinghua, 2015). The calculation formula of kernel density estimation is as follows:

$$f(x) = \frac{1}{nh} \sum_{i=1}^n K\left(\frac{x-x_i}{h}\right), \quad (2)$$

$f(x)$ is the kernel density calculation function at the spatial position of x . When $h > 0$, it is the search radius. K is the kernel function, and $(x-x_i)$ is the distance from the space position of x to the case location of x_i . n is the number of cases within the bandwidth of location x . Kernel density estimation can effectively show the density changes of sexual crimes and highlight the local spatial characteristics of sexual crimes.

3.3. Selection and pretreatment of influencing factors

Previous studies have shown that urban development, urban problems and urban built environment are the three major factors

affecting criminal behavior. From the perspective of geography and urban planning, urban development, urban problems and urban built environment were the three major factors affecting criminal behavior (Jiang, 2018). This study focused on the influence of urban built environment factors (Gong et al., 2021) on the spatial pattern of sexual crimes. In view of the close relationship between sexual crimes and urban commercial and entertainment places (Bai, 2014), the number of urban places such as entertainment and accommodation was taken as the measurement variable of urban built environment to explore the extent of its impact on the spatial pattern of sexual crimes. In addition, hotels, KTV, beauty salons, tea rooms, foot bath massage, chess and card rooms, bars, Internet cafes, baths were the entertainment and accommodation places for public security department to carry out public security management. This study focuses on the effect of commercial service facilities on the spatial pattern of sexual crimes in urban built environment. In a broad sense, urban built environment refers to the artificial environment created by artificial construction, use, maintenance and improvement, and can be measured from multiple perspectives, such as land use mixing degree, transportation accessibility, urban facilities and etc. In view of the close relationship between sexual crimes and the implementation of urban commercial entertainment, the number of various urban functional facilities such as entertainment and accommodation is taken as the explanatory variable to measure the urban built environment, and the degree of influence on the spatial pattern of sexual crimes is explored.

There are 46 types of places that the police need to focus on public security prevention and control in the community policing system. But not all types of places are associated with sexual crimes. This study selects 9 types of places that may be related to sexual crimes, such as hotels, KTV, beauty salons, tea rooms, foot baths, chess and card rooms, bars, Internet cafes, and baths, as influencing factors of commercial service facilities to test the degree of influence on the spatial distribution of sexual crimes. In order to study the built environment factors affecting the spatial pattern of sexual crimes in Haining City from a smaller scale and more deeply and accurately, the number of various facilities and the number of sexual crimes were calculated by using the natural break point method into 5 levels. With the number of sexual crimes occurring in each street as the dependent variable and the number of commercial service facilities as the independent variable, the influence of built environment on sexual crimes was analyzed by using the Geodetector method.

3.4. Geodetector

Geodetector is a group of statistical methods to detect spatial differentiation and reveal the driving force behind it. It can detect the causes and mechanisms of spatial pattern of geographical elements, reveal possible causal relationships, and can be applied to nonlinear models with collinearity among independent variables (Liu and Yang, 2012; Wang and Xu, 2017; Zhu et al., 2015). In this study, factor detection and interactive detection functions of geographic detector are used to explore the influence of environmental indicators of commercial service facilities on spatial pattern of sexual crimes in the central urban area of Haining city.

q is used to represent the interpretation degree of a certain factor X to the spatial differentiation of attribute Y . The specific expression is as follows:

$$q = 1 - \frac{1}{n\sigma^2} \sum_{h=1}^L n_h \sigma_h^2, \quad (3)$$

q is the determination force detection index of environmental factors of commercial service facilities on spatial distribution of sexual crimes. n is the number of samples. $h = 1, 2, \dots, L$ represents the number of secondary areas, which can also be called classification. n_h is the sample number of the second-level region. σ_h^2 and σ^2 are respectively the variances of the tier h and range values Y . The value of q is between 0 and 1. The greater the value of q , the greater the explanatory power of the selected driving factors on the spatial pattern of sexual crimes.

Interaction detection is used to test the effect of interaction between different factors. After the interaction of any two factors, it is necessary to judge whether the factor interpretation power of the two factors on the dependent variable Y is enhanced or weakened, and how much it is enhanced or weakened, or whether the influence of Y on the two factors is independent (Jiang et al., 2021). In this study, the interactive detection function was introduced to judge the explanatory power of the newly generated comprehensive index after the combination of influence factors on the spatial distribution of sexual crimes.

4. Results

This section may be divided by subheadings. It should provide a concise and precise description of the experimental results, their interpretation, as well as the experimental conclusions that can be drawn.

4.1. Temporal characteristics of sexual crimes

According to the theory of time of crime, there is a correlation between season, month, time and crime. A certain criminal behavior occurs at a certain time, and there are differences in the number, type and characteristics of crimes at different times. By using single sample Chi-square to test the samples, it was found that the number of sexual crimes varied significantly with year, month and day, and P value < 0.001 , indicating that there was statistical significance in the variation characteristics of sexual crimes.

The number of sexual crimes presents a "low - high - low" annual change characteristics. From 2014 to 2016, the number of sexual crimes remained at a low and stable state, with an annual average of 28 cases. Between 2016 and 2017, Haining's tourism industry developed rapidly with a year-on-year growth of more than 10 percent. In order to meet the demand of tourism, the supporting

accommodation industry, catering industry and entertainment industry have also developed rapidly. The number of public security facilities which needed to be managed or laid emphasis on has increased rapidly, bringing pressure to social security. In addition, the rapid economic development and the increase of people’s income attracted a large number of migrant workers to seek job opportunities in Haining, which further increased the difficulty of public security management. As a result, the number of sexual crimes soared to 57 and then remained stable at around 60. In 2020, due to the impact of the COVID-19, the tertiary industry was hit hard, tourism-related places closed down or suspended business, the number of tourists and migrants also decreased significantly, and people consciously reduced their going out, which significantly reduced the exposure risk of potential victims. The combination of these factors has led to a precipitous drop in the number of crimes, including sexual crimes, to just 20 in 2020. In 2021, with the normalization of epidemic prevention and control, people’s life gradually returned to normal, tourism and entertainment industries showed a recovery trend, and the number of sexual crimes totaled 36 from January to September (see Fig. 1).

The monthly variation of the number of sexual crimes showed the characteristics of a slow rise at first and then a significant decline, increasing from February, falling in June, reaching a peak in July and then slowly declining. Most victims of sexual crimes were women, and summer was the peak season for sexual crimes. On the one hand, the temperature in July obviously rised and women wore less, so potential criminals were easy to produce the idea of crime. Also, summer was easy to cause people to produce impatient mood, emotional impulse more, temporary and passion crime cases would be more frequent. On the other hand, in summer, the opening hours of entertainment places were extended, nightlife was abundant, and social activities were increased, which resulted that women’s exposure risk was increased, and frequent dinner parties and other recreational activities would increase the probability of deviant behaviors such as drunken disturbance. Drunken men were prone to irrational behaviors, while women’s vigilance and self-protection ability were decreased, and the possibility of successful sexual crimes would also increase. Winter had low sexual crime rate. In winter, the climate was cold, women wore conservative clothes, reduced entertainment and social activities which greatly reduced women’s exposure risk. Moreover, outdoor crime environment was no longer available in low temperature weather, and indoor places had strong social supervision and was relatively difficult to commit sexual crimes. So sexual crimes in winter were effectively suppressed (see Fig. 2).

The number distribution of sexual crimes in 24 h a day has two peaks (1, 22 o’clock) and three valleys (5, 11, 18 o’clock)). Night was the most frequent period of sexual crimes, among which 193 sexual crimes occurred from 19 p.m. to 4 a.m. of next day, accounting for 62%. Social activities were concentrated during this period, and entertainment such as dining and drinking increased the probability of sexual misconduct, so social supervision was at its weakest during the day. In addition, the night was dark with poor vision. The victim was not easy to see the appearance and characteristics of the criminal suspects, which was convenient for the criminal to hide before committing the crime and escape after it. From the perspective of psychology, thinking activities and emotional activities

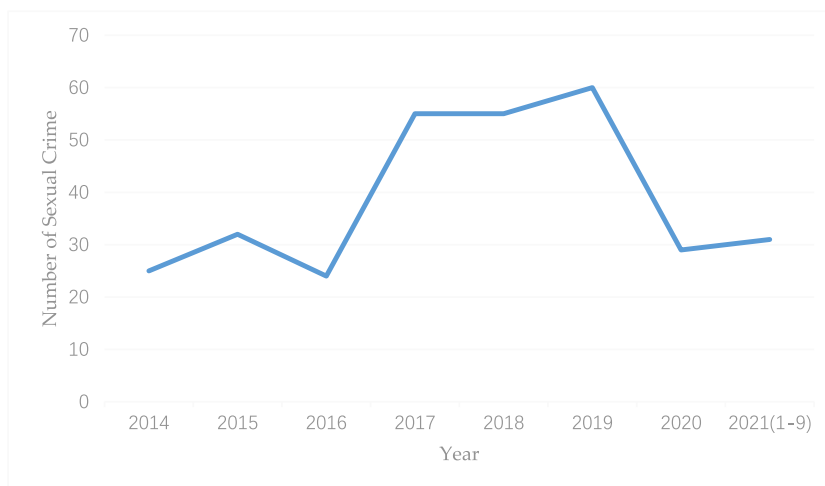
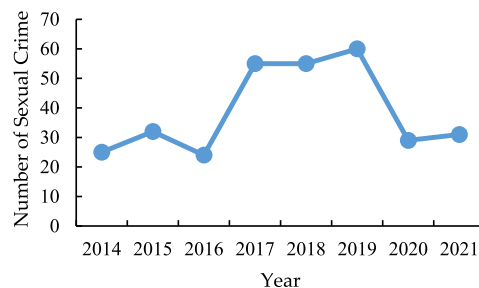


Fig. 1. Annual change in the number of sexual crimes.

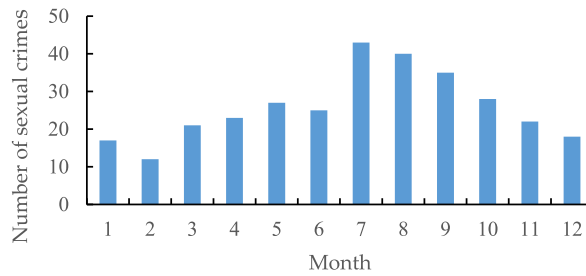


Fig. 2. Monthly change in the number of sexual crimes.

restricted each other. At night, human beings were mainly driven by emotional activities and amplified their desire which resulted in their impulsive act and increased the probability of crime. In the daytime, people were predominated by rational thinking, and bright light with more pedestrians increased the difficulty of crime. The three low points in the daytime respectively correspond to the meal time of the criminal and potential victims in the morning, noon and evening. The personnel activities were reduced, and it was difficult to meet the three crime conditions which were crime environment, motive and impulse at the same time (see Fig. 3).

4.2. Spatial characteristics of sexual crimes

Hypothesizing that sexual crimes occur randomly at any time and place, the average distance between a crime place and the nearest crime place, namely the expected distance, was respectively 428.17 m, 683.06 m and 490.29 m within 24 h of a day, 12 h of the day (5–18 o'clock) and 12 h of the night (19-4 o'clock the next day). However, the actual observed distances were respectively 300.10 m, 554.17 m and 367.59 m. Therefore, their nearest neighbor indices are 0.70, 0.81 and 0.75, all below 1, indicating that sexual crimes were more concentrated in both day and night than the assumed arbitrary distribution. The result was significant at the 99% level. Among them, the observed distance, actual distance and nearest neighbor index of sexual crimes at night were smaller than those during the day, indicating that the spatial distribution of sexual crimes at night was more concentrated in some specific places and the frequency of crimes was higher. Therefore, the police should focus on the night period, and strengthen the control of some specific places where sexual crimes occur frequently during this period (see Table 1).

We using standard deviation ellipse and kernel density estimation to further display the spatial distribution pattern of different time period crimes. As shown in Fig. 4, total sexual crimes and night sexual crimes were mainly distributed along the north-south axis, while daytime sexual crimes were distributed along the northeast-southwest axis. Hot spots of sexual crimes were concentrated in the center of the old urban area of Haining, which was the largest transportation hub and commercial center of Haining. There were many entertainment venues, hotels and floating population in the area, which brought a lot of public security pressure and became a hot spot area. The dense residential area in the northwest of Haining city was another high incidence area of sexual crimes. The area was dominated by old communities and urban villages. The personnel composition was complex, and the majority of migrant workers formed a favorable environment for sexual crimes.

It was found that sexual crimes were clustered in the central area of Haining City, displayed as a spatial pattern of "two centers, one district, multiple nodes", as shown in Fig. 4(1). The northern "center" was near Haining Railway Station, Aegean Shopping Plaza and People's Square in the south, covering Workers' Road pedestrian street. This area was one of the most prosperous commercial blocks in Haining, with many entertainment places, hotels, shops, office buildings, and etc. The complete entertainment, transportation and business facilities attracted a large number of citizens and tourists to come and consume. Therefore, the population density and the floating population was large. The southern "center", with Intime shopping mall as the core which was the largest single shopping center in Haining, was the new entertainment and consumption center of Haining. Together with the northern commercial center, it assumed the commercial and entertainment functions of the city. A large number of rural residents in the south and the youth in urban area were the main customer groups of the new commercial center. "One Area" was a dense residential area to the southeast of the

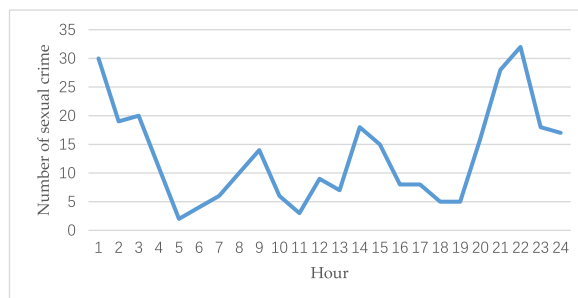


Fig. 3. Hourly changes in the number of sexual crimes.

Table 1
The results of ANN analysis.

Type of case	Observation distance/m	expectation distance/m	Nearest Neighbor Index(NNI)	Z score	P Value
Sexual Crime	300.10	428.17	0.70	-10.09	0.00
Day crime	554.17	683.06	0.81	-3.92	0.00
Night crime	367.59	490.29	0.75	-6.65	0.00

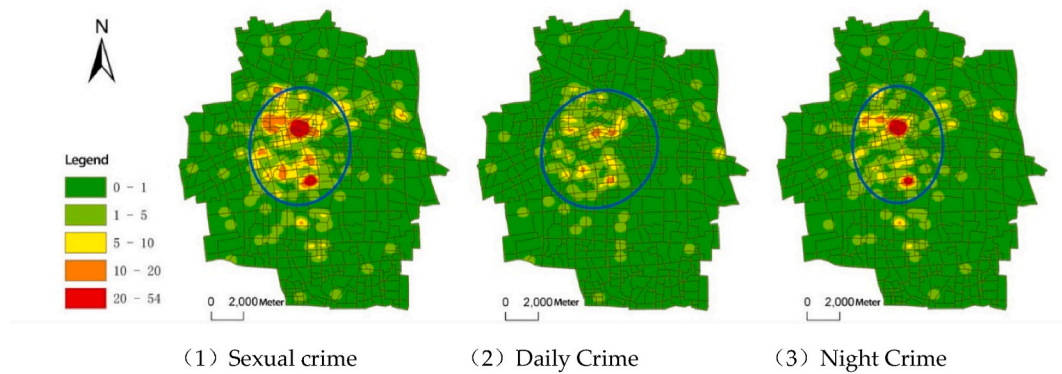


Fig. 4. Spatial distribution characteristics of sexual crime.

intersection of Luolong Road and Haining Avenue. It comprised several residential communities, which were dominated by old flat communities and urban villages. The population composition in this area was complex, and the majority were migrant workers. The community has no property management with old street lamps and other lighting facilities. There was a large area of monitoring blind area. Therefore, it was easy to form a favorable crime environment in this area, which led to crimes frequently happened in this area. Together with the two commercial centers in the north and the south, this area constituted the hot spot of Haining sexual crimes. "Multi-node" included residential areas composed of Jing Chang and Shuang Feng neighborhood, Xin Yue Hua Yuan neighborhood, and neighborhood composed of Jinxiu Garden, Xing Cheng Luo Zhou, Nanyuan Community and etc. These nodes were either urban villages without management, prospective houses without monitoring lighting facilities installed, or urban commercial sub-centers with dense entertainment facilities. It could be seen from the above spatial distribution pattern that there was a certain spatial relationship between the intensity of sexual crimes and environment, especially commercial and residential areas where sexual crimes were most common.

By comparing Fig. 4 (2) and (3), it can be seen that the spatial distribution characteristics of sexual crimes were different during the day (5-18 o'clock) and at night (19-4 o'clock the next day). The number of daytime sexual crimes was relatively small (118 cases), accounting for 38% of the total, and there was no obvious crime hot spot in space. It showed a spatial pattern dominated by residential communities and scattered distribution of multi-nodes. Sexual crimes occurred frequently at night (193 cases), accounting for 62% of the total, and there were two obvious crime hot spots in space, corresponding to the two commercial centers in the north and south of Haining City.

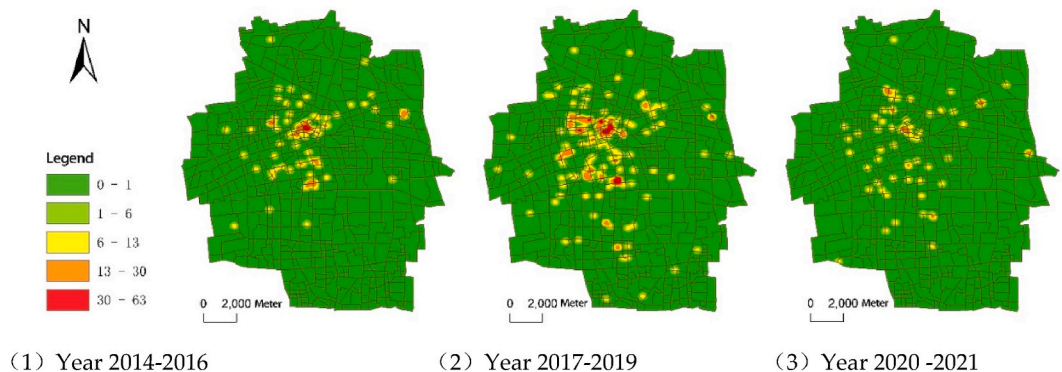


Fig. 5. Evolution process of spatial characteristics of sexual crime.

4.3. Spatial evolution characteristics of sexual crimes

Since the annual variation of the number of sexual crimes had a certain regularity, it was divided into three periods (2014–2016, 2017–2019 and 2020–2021) according to the annual variation characteristics. By comparing the spatial distribution pattern of each period of crimes (Fig. 5), an obvious spatial evolution process could be found.

The first period (2014–2016) showed a spatial distribution pattern of "one center and multiple nodes", with the junction of Gongren Road and Haichang Road as the center and distributed radially outward. Before 2016, the new commercial center in the south was in the construction. The commercial and entertainment facilities had not yet taken shape, and the urban form was a "single core" structure. The Haining Railway Station and Aegean Shopping Park in the north were the only core areas of the city, corresponding to the hot spot of "one center" sexual crimes. In addition, this period was the peak of commercial housing construction in Haining City, and the newly built communities were mostly built around the northern commercial center. In the uncompleted communities, the residential population was small, and there were many monitoring blind areas, which were easy to become the ideal location of sexual crimes, thus forming a "multi-node" hot spot.

In the second period (2017–2019), with the rapid development of tourism and the economic growth in Haining City, the increase of floating population and the development of entertainment industry led to an increase in the number of sexual crimes. The number of crime hotspots increased significantly. In the meanwhile, the construction of the southern Yintai City Business District had been completed, and the corresponding supporting facilities had been improved. The city had changed from a single-core structure to a dual-core structure. The southern business district had become a new hot spot for sexual crimes, and the sub-centers of other cities had also been developed, so the sexual crimes presented a new "multi-center, multi-node" mode. In addition, due to the completion of the southern commercial center, the central urban area expanded outward, which not only increased the number of commercial houses built around it, but also transformed the original villages and towns into villages within the city. The population density, the number of floating population and the housing price all increased significantly, resulting in the difficulty of public security management in the southern suburbs where became a new "node" with high density of sexual crimes.

In the third period (2020–2021), the area of high-incidence areas of sexual crimes decreased but the number was basically the same as that during 2014–2016, showing a "multi-node" spatial pattern. This indicated that the concentration degree of sexual crimes decreased in this period. In 2020, due to the impact of the Covid-19 epidemic, the number of sexual crimes dropped off a cliff, with the annual total number of sexual crimes only 30. In 2021, with the normalization of epidemic prevention, people's life gradually returned to normal, and sexual crime reached to 36 cases from January to September. Additionally, the frequent sexual crimes in the commercial center attracted great attention from the society. The police increased their attention to the entertainment facilities in the commercial center, with increasing the number of patrols and providing more police support. So the number of sexual crimes decreased significantly in the both commercial core areas in the south and north of the city. In addition, with the completion of the construction of houses, monitoring and lighting facilities, the residents moved into the community and strengthened social supervision. With the disappearance of the favorable crime environment, the hot spot area of the southeast and the west of the former uncompleted communities disappeared, but a new hot spot area appeared near a village in the east of the Xiashi District. It was mainly related to the rise of the rent price of urban villages, which resulted in the migration of floating population moving to outside with lower rent.

4.4. Independent analysis of influencing factors

Table 2 shows the factor detection and analysis results of different commercial service facilities on sexual crimes. It indicates that the bathing place has passed the significance test of 10%, while the other 8 types of commercial service facilities have passed the significance test of 1%. In other words, these 8 variables are important driving factors affecting the spatial distribution of sexual crimes. Among them, the size of q value indicates the extent to which the dependent variable Y is affected by the independent variable X. The explanatory power of 9 functional facilities on the spatial distribution of sexual crimes in order from large to small is KTV > Internet cafe > hotel > Beauty salon > foot bath massage > Chess and card room > bar > tea room > bath. It shows that different built environment factors have different degrees of influence on the spatial differentiation of sexual crimes, which is closely related to the nature of places., The q values of KTV, Internet cafe and hotel are large, indicating that these three types of facilities have a relatively

Table 2
The impact of different commercial service facilities on sexual crime.

Commercial service facility	q value (%)	p value
Hotel	35.77	0.00***
Bar	16.78	0.00***
Tea room	16.37	0.00***
Beauty salon	28.51	0.00***
Foot bath massage	25.26	0.00***
Chess and card room	18.05	0.00***
KTV	38.33	0.00***
Internet cafe	37.83	0.00***
Bath	6.23	0.07*

***P < 0.01 , **P < 0.05 , *P < 0.1.

large impact on the spatial differentiation of crime and a large explanatory power; the q values of tea room, bath and other facilities are small, indicating that these facilities have a relatively weak impact on the spatial differentiation of crime and a small explanatory power.

KTV is a common place of entertainment where could explain the spatial distribution of sexual crimes at the level of 38.33%. It is a unit that carries out activities with strong privacy and dim environment. Therefore, inspectors are difficult to supervise, and it is easy for perpetrators of sexual crimes to carry out criminal acts. Same as KTV, Internet cafes are open 24 h, and the customers are mainly males aged 18–35, which is the main group of sexual crimes. In addition, in order to reduce business costs, Internet cafes are mostly located in alleys with low road grade, fewer pedestrians, more difficult supervision, and easy to generate sexual crimes. This factor can explain the spatial pattern of sexual crimes at the level of 37.83%. Hotels are among the most private places, can completely form a temporary closed independent space. Criminals often bring victims to the hotels through cajoling, abduction and coercion. Facilities such as tea rooms and baths are more open and easy to police, rape and molestation are easily exposed, and victims are provided with the opportunity to seek help. So sexual crimes are less likely to occur in such spaces.

4.5. Interactive analysis of influencing factors

The explanatory power of a single type of urban facility on the spatial distribution of sexual crimes is less than 50%, indicating that sexual crime is the result of the collective action of multiple facilities. Therefore, the interactive detection function of geographical detector was used to test the effect of commercial service facilities superimposed on the spatial differentiation of sexual crimes, and 36 pairs of interaction results were obtained as shown in Table 3. After the interaction detection among the nine independent variables, the phenomenon of double factor enhancement appeared, that is the explanatory power of the factor increased significantly after the interaction of the two variables. It can be seen that the interaction between commercial service facilities factors has a greater impact on the spatial differentiation of sexual crimes than the original single factor, indicating that the incidence of sexual crimes in areas where multiple facilities are mixed increases significantly.

The interaction factors with explanatory power >60% included Internet bar and foot bath massage (q = 68.68), Internet bar and KTV (q = 61.15), and foot bath massage and KTV (q = 60.25). The consumers of Internet cafes are mainly teenagers and middle-aged men, who belong to high-risk criminal groups according to the portraits of sex offenders, while some foot bath and massage shops provide prostitution services, which further induces high-risk criminal groups to put criminal ideas into practice, especially high-risk criminal groups who are mainly male teenagers under 22 years old and lack economic ability. In addition, the shops of Internet cafes and foot massage shops are small, and they tend to avoid the main road and are distributed along the roads below the second level in communities and villages in cities. Therefore, they lack social supervision, and they are easy to become the patrol blind area of the police, constituting a crime situation conducive to committing crimes. It will further promote potential criminals to form criminal motives and commit criminal acts. KTV is similar to foot bath massage, which is a common entertainment place that provides prostitution services. It has a lot of small rooms which are confined space, with the environmental conditions for the implementation of crimes. These areas with large density is more prone to sexual crimes. The explanatory power after interaction of KTV and chess and card room, Internet bar and beauty salon facilities is >55%. The former is more difficult to manage because there are more idle people in chess and card room, while KTV provides an environment convenient for committing crimes. The latter, due to the large number of high-risk criminal groups around Internet cafes, and the customers of beauty salon facilities are mainly young women, easy to become potential criminal targets and promote the occurrence of sexual crimes. Therefore, it is possible to arrange video surveillance and police patrol points in the corresponding facilities for the combination of scenes with greater interactive impact, such as Internet cafes and foot bath massage, Internet cafes and KTV, foot bath massage and KTV, and etc. It could enhance the monitoring effect, which may indirectly inhibit sexual crimes or promote the investigation of sexual crimes.

5. Discussion and conclusion

According to crime pattern theory, the place of crime occurrence was not randomly distributed in the city, and the built environment affected the crime pattern in many aspects (Brantingham and Brantingham, 1995). Some specific built environment was the main attraction of crime and the place where crime occurred (Ceccato, 2014; Ceccato et al., 2019). In this study, the main attraction of crime and the place where crime occurred included hotels, KTV, beauty salons, teahouses, foot baths, chess and card rooms, bars,

Table 3
Detection results of the interaction of commercial service facilities.

Commercial service facilities	KTV	Tea room	Bar	Beauty salon	Chess and card room	Foot bath massage	Bath	Hotel	Internet cafe
KTV	38.33								
Tea room	42.59	16.37							
Bar	50.84	44.07	16.78						
Beauty salon	46.51	42.07	43.16	28.51					
Chess and card room	58.17	39.38	45.38	47.63	18.05				
Foot bath massage	60.25	40.30	48.51	49.82	49.61	25.26			
Bath	43.25	23.51	24.18	41.82	25.52	36.43	6.23		
Hotel	54.88	42.47	50.74	51.34	52.72	53.72	45.28	35.77	
Internet cafe	61.15	49.17	45.70	56.79	50.32	68.68	49.89	53.35	37.83

Internet cafes, baths. Routine activity theory and crime pattern theory emphasized the interaction between offenders, victims and monitors, as well as the spatio-temporal interaction between people and the environment (Feng et al., 2019). From the time distribution characteristics of sexual crimes, the activities of offenders and victims changed over time, and the number of sexual crimes also changed with the change of the number of out-of-town population in different time periods. The space of sexual crimes was concentrated in the commercial and residential areas, where the population was dense, the commercial service facilities were complete. The activity space of potential offenders and potential victims overlap. The spatio-temporal characteristics of sexual crimes conformed to routine activity theory (Cohen and Felson, 1979) and crime pattern theory (Bottoms et al., 2002).

Sexual crimes have seriously violated women's personal rights and caused irreparable psychological trauma to female victims. Preventing crime is an important duty of police to maintain social public security order. Based on the data of sexual crimes in the central urban area of Haining City, Zhejiang Province from January 2014 to September 2021 and the POI data of places needing attention, this paper analyzes the spatial and temporal distribution and evolution characteristics of sexual crimes from a geographical perspective, and analyzes the impact of commercial service facilities in the built environment on the spatial pattern of sexual crimes by using Geodetector of Excel version.

Firstly, the time distribution of sexual crimes in Haining City presents the characteristics of "low-high-low" annual and monthly changes. From 2014 to 2016, the number of sexual crimes remained at a low and stable trend. Later, due to the rapid economic growth driven by the development of tourism, the number of sexual crimes increased and remained at a high and stable state of about 60. In 2020, due to the impact of the COVID-19, the number of sexual crimes fell off a cliff. Later, with the normalization of epidemic prevention and control, people's life gradually returned to normal, tourism and entertainment industries showed a recovery trend, and the number of sexual crimes rose to 36. In terms of monthly changes, it showed the characteristics of a slow rise and then a significant decline, increasing from February, falling in June, reaching a peak in July and then slowly declining. Summer is the high incidence season of sexual crimes. The daily variation of sexual crimes has two peaks (1, 22 o'clock) and three valleys (5, 11, 18 o'clock), and the night is the peak period of sexual crimes.

Second, the sexual crime cases in Haining City are clustered in commercial and residential areas. The overall spatial pattern is presented as "two centers, one area, and multiple nodes". According to the time of crime occurrence, it is found that the observed distance, actual distance and nearest neighbor index of sexual crimes at night are smaller than those during the day, indicating that sexual crimes frequently happen at night, and has more concentrated spatial distribution. There are two obvious crime hotspots in space, corresponding to the two commercial centers in the north and south of Haining City. However, the number of daytime sexual crimes is small, and there are no obvious hot spots, showing a spatial pattern dominated by residential communities and scattered distribution of multi-nodes.

Third, the spatial pattern of sexual crime cases has undergone an evolution process from "one center, multi-node" (2014–2016) to "multi-center, multi-node" (2017–2019) and then to "multi-node" (2020–2021). The transformation of the first period is mainly related to the economic development driven by tourism, the transformation of the city from a single-core structure in the north to a dual-core structure in the north and the resulting change in the location choice of commercial housing. The second period is more related to the epidemic, the rise of urban land prices and the transfer of floating population to the outskirts of the city. The rural-urban fringe is becoming a new hot spot for sexual crimes.

Last but not least, hotel, KTV, beauty salon, teahouse, foot bath massage, chess and card room, bar, Internet bar and bath have a significant correlation with the spatial distribution of sexual crimes. Sexual crimes were concentrated in entertainment areas characterized by bars, nightclubs and restaurants. (Ceccato, 2014; Ceccato et al., 2019; Muldoon et al., 2019), especially if there was a high concentration of alcohol services nearby (Hewitt et al., 2018). The combination of these facilities and factors greatly improves the explanatory power of the spatial pattern of sexual crimes. Among them, KTV and hotels have strong privacy, while customers of Internet cafes are mainly male aged 18–35, who is a high-risk group of crime. All these three places are 24 h of business, which can explain the spatial distribution of sexual crimes at more than 35% level. The explanatory power of interaction between Internet bar and foot bath massage, Internet bar and KTV, and foot bath massage and KTV was significantly increased, reaching more than 60%, indicating that the incidence rate of regional crimes in the mixed gathering of multiple facilities was significantly increased.

According to the results of this study, some suggestions can be provided for the effective development of the rectification and prevention of sexual crimes in Haining City. First, the prevention of sexual crimes in the future should focus on the hot spots of sexual crimes, such as the two commercial core areas in the north and the south. Second, the police should strengthen the patrols at 22 and 1 o'clock at night, focusing on hotels, KTV, beauty salons, foot massage, Internet cafes and other 24-h business places. Third, the police should increase the investigation of entertainment venues that may be involved in pornography, and carry out spot checks on enclosed spaces such as private rooms.

This study is a useful attempt to explore the change of temporal and spatial pattern of urban sexual crimes and the influencing factors of commercial service facilities, but there are still some limitations. First, the data is official data, but some sexual crimes have not been all reported to police. So there are some data bias. Second, when exploring the influencing factors of the spatial distribution of sexual crimes, only the influencing factors of commercial service facilities were considered, and other artificial environment indicators such as land use were not considered. Third, the commercial service facilities selected in this paper are statistical data based on time nodes, and there are certain errors between the data obtained by this selection method and the panel data of sexual crimes for analysis. Therefore, it is necessary to comprehensively consider the difference in data selection time in the subsequent research. In the future, land use types and road network data can be combined to explore the impact of different built environments on the spatial distribution of sexual crimes. Sexual crimes can also be subdivided into indecent assault crimes and rape crimes, and the differences in spatial and temporal distribution and influencing factors between the two subcategories can be compared, so as to put forward more targeted crime prevention and control suggestions.

Funding

This research was supported by the Zhejiang Provincial Natural Science Foundation of China under Grant No. LY23D010001 and the National Natural Science Foundation of China under Grant No. 41901160.

CRediT authorship contribution statement

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Declaration of competing interest

None.

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