To Resilient Peaceful Campus-relationship: Security Evaluation and Optimal Design for School Outdoor Environment Based on Spatial Syntax*

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Abstract.

A Large number of teenagers worldwide are suffering from school violence, especially inside schools. Nevertheless, the current international approaches to preventing violence are still dominated by social ones such as strengthening surveillance and establishing regulations, which are not ideal for outdoors, whereas prevention through environmental design would be more effective. For this purpose, this paper evaluated the security of school outdoor environment (SOE) and then designed for optimization, with case L in southern Zhejiang Province, China, as the research site. Through a full questionnaire, information about the outdoor violence (types, times, locations, etc.) and students' current evaluation of SOE (N=338, 50.59% female) were obtained and further developed into violence occurrence maps. The spatial security of SOE was also evaluated using DepthmapX software based on spatial syntax theory, including configuration (integration, mean depth, connectivity, control, and intelligibility) and visibility (visible connectivity in summer and winter). And then the relationship between the spatial security of SOE and the violence occurrence was explored, combined with the maps and evaluation results. Furthermore, the four violence spaces were summarized, with optimal design strategies proposed accordingly. It was found that, briefly, (1) Integration, mean depth and connectivity of the spatial configuration were strongly correlated with the outdoor violence distribution and vary across types. Physical conflicts and external invasions occurred mostly in areas with low integration and high mean depth. (2) Visible connectivity of spatial visibility showed differences due to changes in deciduous trees in different seasons, as well as having an impact on the outdoor violence distribution in each type. More severe violence, such as physical conflict, often happened in areas with very minimal visible connectivity. (3) Bridging cut-offs and planting low shrubs/high canopy trees were convenient and effective strategies to improve spatial configuration and visibility. The results represented that there are still many challenges in the application of spatial syntax, but this method has great potential in evaluating the security of SOE as well as predicting the violence occurrence, which may fill the gap of current school planning to resilient healthy and peaceful campus-relationship.

Abbreviations: SOE: school outdoor environment.

Nomenclature: Int: integration; **MD:** mean depth; **Conn:** connectivity; **Cont:** control; **VC:** visible connectivity; **VCs:** visible connectivity in summer; **VCw:** visible connectivity in winter.

Keywords: school violence, school outdoor environment (SOE), Spatial Syntax, security evaluation, optimal design

1. Introduction

Schools are supposed to be places with harmony and stability, but in recent years, student violence incidents have occurred frequently. There are various forms of campus violence, including physical conflict, social violence such as verbal intimidation and group isolation, as well as conflict between teachers and students (UNESCO, 2017). The long-standing school violence may affect the teaching order, campus living environment and students' healthy growth to varying degrees, especially damage students' physical and mental health and cause huge psychological disorders (Riehm et al., 2021; Ferrara et al., 2019). At the same time, school violence is also a global social problem. According to the report published by UNESCO in 2018, about 246 million children around the world were undergoing different forms of school violence, and the number of violence incidents in boarding schools was much higher than the average level (UNESCO, 2017; UNESCO, 2018). In China, with a huge population receiving compulsory education, a total of 916,000 primary and secondary schools disappeared during the period from 1976 to 2016 with most rural schools dismantled and merged, and so the boarding school has become the most common school type in Chinese education system (Ministry of Education, PRC, 2018). Meanwhile, relevant surveys showed that the incidences of all school violence types in boarding schools were higher than those in ordinary schools in China (Wang , 2016). It can be seen that it's urgent to carry out the researches on the violence prevention in boarding schools, especially for developing countries represented by China.

At present, most schools around the world have carried out the prevention and control focusing on security education. In the meantime, they have also taken active intervention measures such as increasing monitoring equipment (Zeng et al., 2018) and establishing teachers' own authority through self-report intervention (Burger et al., 2015). In some countries, school violence has been incorporated into the regulations of teenagers for legal restraint (Foody et al., 2018; Kalichman & Brosig, 1992; Kim, 2015). Relevant "Social Prevention" measures also include peer support (Cowie, 2011), such as the curriculum system plan for protecting students from violence formulated and launched by the Finnish Ministry of Education (Sairanen & Pfeffer, 2011). These social intervention measures have an ideal effect on the prevention of indoor violence to a certain extent. The outdoor environment has increased the possibility of violence due to the lack of human access, insufficient lighting, and other problems (Bradshaw et al., 2014; Kim & Jung, 2018), but little attention has been paid to the security efforts of "Physical Prevention" of school outdoor environment (SOE) design.

Based on long-term research and practice of numerous scholars, a relatively complete theoretical system has been established for the research on the relationship between outdoor environmental design and criminal behavior (Atlas, 2013; Frank et al., 2011; Cozens et al., 2005; Armitage, 2018). In 1961, Jane Jacobs analyzed the sense of security of street space from a sociological perspective (Jacobs, 1961) and put forward the concept of "Street Eye". In 1971, C. Ray Jeffery first put forward the Crime Prevention through Environmental

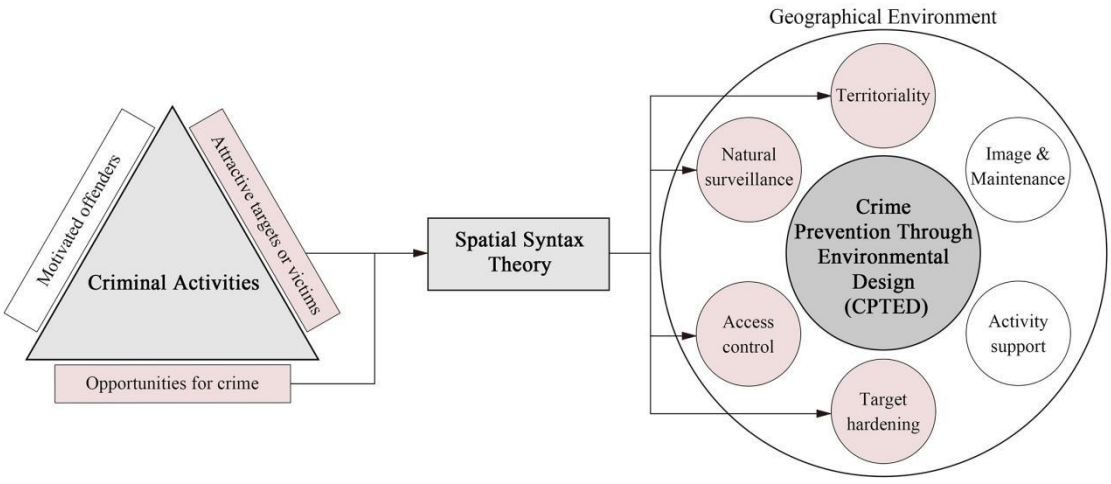
Design (CPTED) (Jeffery, 1971). which centers on the idea that the design of the built environment can effectively weaken the fear of crime and reduce the incidence of crime. In 1972, Oscar Newman first proposed the concept of "Defensible Space" (Newman, 1972), advocating providing more surveillance opportunities through small plots in residential area planning, thereby creating a community environment that can be controlled by residents. James Q. Wilson and George L. Kelling proposed "Broken Windows Theory" (Cozens & Love, 2015) in 1982, indicating that when the environment that lacks maintenance and management in the system might give a positive signal to potential criminal behavior. Many theories have also studied the characteristics of criminal behavior (Airaksinen et al., 2021), focusing on the analysis of the causes of frequent crime in some specific places in the city, such as "Rational Choice Theory" (Alsharif et al., 2020), "Behavioral Geography Theory" (Bernasco, 2007), etc. The CPTED theory in this study aims to reduce the opportunity of crime through enhancing natural surveillance, establishing clear site attributes, and maintaining the image of spatial environment, etc. Based on the existing research results (Piroozfar et al., 2019; Mihinjac & Saville, 2019; Wahab et al., 2018; Gibson and Johnson, 2016), CPTED can be summarized as the following six interrelated core elements, namely territoriality, natural surveillance, access control, activity support, image & maintenance, and target hardening, as shown in **Tab. 1**.

Table 1: Six elements of CPTED theory with their definition and purpose

Element	**Definition**	**Purpose**
Territoriality	Attributing the ownership manifested by space or things, and expressing a sense of ownership and pride.	To convey to others that an area is claimed and cherished, enhance people's vigilance and surveillance, and reduce the possibility of crime (Crowe, 2000).
Natural surveillance	Surveillance is divided into natural surveillance and physical surveillance, including equipment installation, and deployment of security personnel.	To eliminate potential visual blind spots to facilitate observation and maximize visibility, increase the sense of security of students and staff, and reduce the possibility of crime (Crowe, 2000).
Access control	Using real or perceptible obstacles to strengthen the control of personnel entering and leaving specific areas.	To improve comfort and reduce prohibited behavior by providing safe routes and restricting unauthorized access (Lamoreaux & Sulkowski, 2020).
Activity support	Manually increasing the facilities and services of the place.	To attract human traffic and increase the natural surveillance in the environment by enriching the functions and activities of the place, such as commercial placement, entertainment activities and public welfare performances (Lamoreaux & Sulkowski, 2020).
Image & Maintenance	Carrying out the repair, replacement and general maintenance of the building or area to allow it to demonstrate good external condition.	To attract people to stay and gather by using a beautiful environment and further convey a sense of ownership and care, thus facilitating crime prevention (Lamoreaux & Sulkowski, 2020).
Target hardening	Strengthening the protective measures for specific targets	To control the flow of people by setting or heightening fences, installing protective fences and anti-theft windows, etc., thereby reducing prohibited behaviors (Arabi et al., 2020).

Although CPTED theory has been widely applied in urban residential areas (Liu, 2014; Rupp A et al., 2020), green parks (Surette & Stephenson, 2019; Mingyun et al., 2018; Hong, 2017), hospitals (Sun, 2017), industrial parks (Peiser & Chang, 1998), public transport (Jones & Sloboden, 2017) and other diversified space types, it's less applied in the SOE prone to violence. Some scholars have begun to combine CPTED theory with geo-information technology (Takizawa et al., 2010). For example, Texas State University used this technology to identify and predict crime. Alternatively, Spatial Syntax theory was used to analyze the impact of spatial layout on crime in communities or cities (Aziz, 2020; Matijosaitiene, 2016), for instance Noha Ahmed Abd El AZIZ applied the method to measure the safety of small and medium-sized urban parks (Aziz, 2020). The Spatial Syntax theory here is a quantitative analytical model used to describe the quality of urban built environment, comprising a series of indicators used to quantify and analyse buildings and urban spaces. Bill Hillier and Julienne Hanson put forward the Spatial Syntax theory (Hillier & Hanson, 1984) in the 1980s and defined it as "an objective way to explain human behavior and social activities from the perspective of spatial and morphological layout". Based on the topological attributes of space (Michael J. Ostwald, 2011), this theory provides a series of tools to analyze the linguistic characteristics of space, such as configuration, user choice and visibility, making it an important means to explore the relationship between space environmental design and criminal behavior, as shown in **Fig. 1**. Changing the attractiveness of the spatial environment may reduce the criminal opportunities of suspects, so as to affect the design of such elements as Territoriality, Activity Support and Image & Maintenance in CPTED theory (Aziz, 2020). Spatial Syntax theory may not only verify this influence relationship, but also guide and improve the design of spatial environment through a series of simulation tools, thus realizing crime prevention. In order to better understand and prevent school violence, it's necessary to deeply understand the space types highly correlated with the violence types, and the spatial characteristics and quantitative data of these spaces. Therefore, this study applied Spatial Syntax theory as the main analysis means to evaluate the public security of SOE in boarding school through depthmapX software.

Figure 1: The relationship among criminal behavior, spatial syntax and CPTED theory.



In addition, research and practical projects on school violence have mainly focused on ordinary schools in urban areas (Zeng et al., 2018; Lamoreaux & Sulkowski, 2020; Vagi et al., 2018; Nettle et al., 2012), with very rarely studied for boarding schools (Shariati & Guerette,

2019). Based on an empirical study of 17,841 boarding school students in China, Wu Fangwen et al. found that the probability of violence in boarding schools was much higher than in areas such as Hong Kong, Macau and Taiwan in China (Lin, 2018), and that the probability of violence was higher for boys at 18.46% than for girls at 13.42%. Newcastle University, UK, ever carried out an experiment called "Eye of surveillance" on the phenomenon of frequent school thefts of bicycle (Zeng et al., 2018). And by putting up posters to intimidate potential criminals, the university saw the number of bicycle thefts halved after 12 months. A serious campus shooting occurred at Sandy Hook Elementary School in the United States in 2012, in which many students and teachers were killed. After the incident, Jay Brotman conducted the re-planning and redesign for the school based on CPTED theory (Nettle et al., 2012). There are also numerous related practical projects in countries such as South Korea (Kim et al., 2019), illustrating the substantial application of CPTED theory in the design of urban campus environments. However, most of the research and practice described above are interventions for some criminal cases (related to the law), which are fundamentally different from school violence prevention (not necessarily criminal), and there is a gap in research for the unique type of spatial environment type in boarding schools.

To sum up, in view of the increasingly prominent issue of school violence, especially in boarding schools, in addition to social prevention methods such as security patrol and security education, it's also necessary to carry out the security prevention and control design for SOE. Therefore, this paper attempted to comprehensively use CPTED and Spatial Syntax theory to evaluate the security of the SOE in boarding schools. Based on the exploration of the relationship between the spatial characteristics of SOE and the occurrence of outdoor violence, this paper classified the violence occurrence space, and put forward the corresponding optimization strategies. The research results are expected to fill a gap in current school safety planning by providing a more effective way of assessing and predicting outdoor violence prevention in boarding schools and other types.

2. Materials and methods

2.1 Field survey

2.1.1 Selection principles of case model

Boarding schools were chosen as the case study type for this research because of the specificity and typicality of such schools for the following reasons.

- Universality of school type. According to statistics from the Ministry of Education (Ministry of Education, PRC, 2012), after 2012, the number of boarding students in compulsory education of China has reached 32.765 million, accounting for 21.85% of the total number of students in schools. As can be seen, boarding schools are common in China and research into their school violence is somewhat universal.
- Diversity of building functions. Unlike ordinary day schools, boarding schools not only have infrastructures such as teaching buildings, office buildings and gymnasiums, but also have dormitories and other facilities to serve the daily lives of students. Thus, the diversity of building functions increases the space where outdoor school violence may occur to a certain extent.

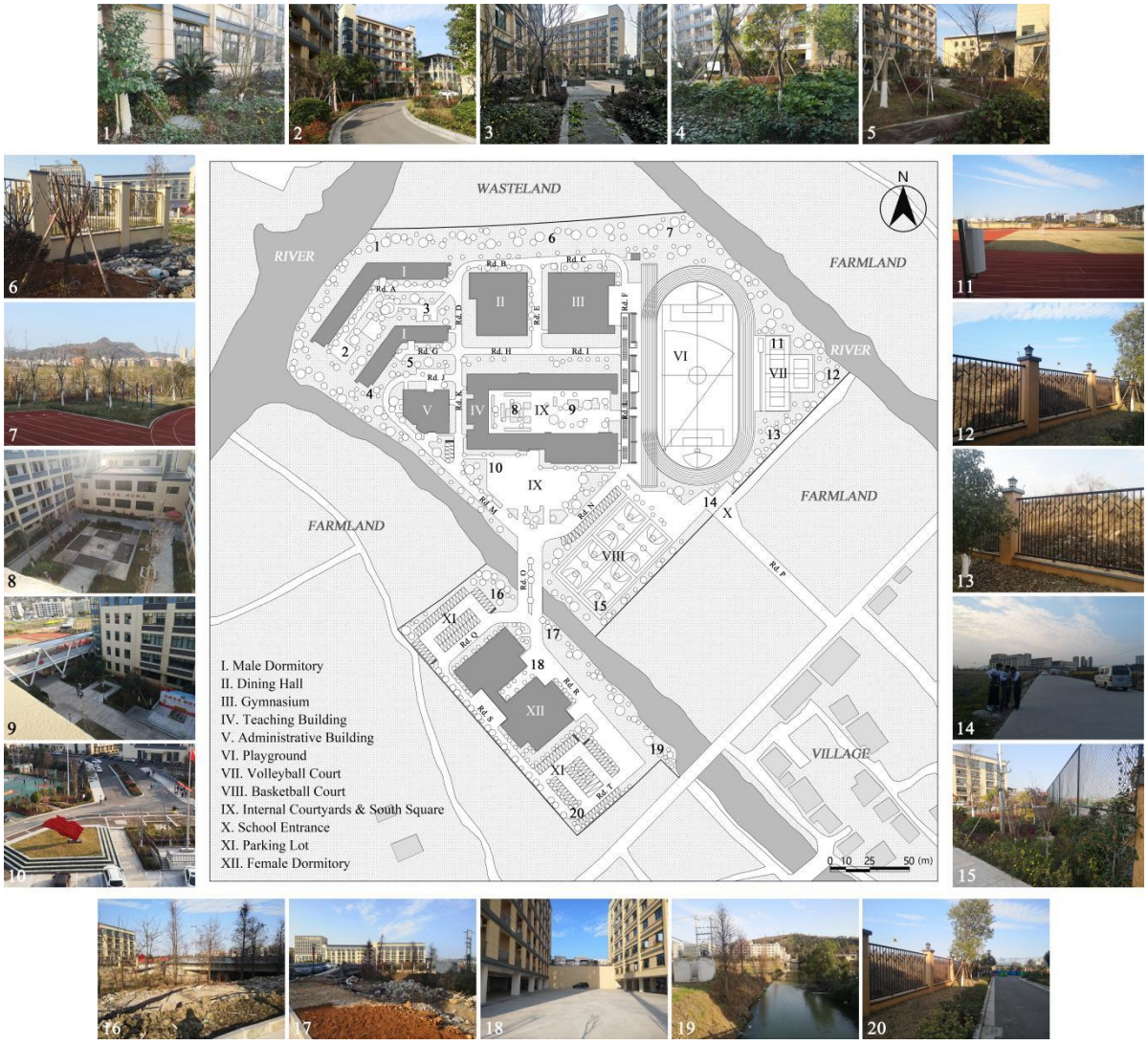
- Specificity of the student population. Most students in boarding schools are left-behind children (Li, 2018), whose parents are often in the labour force. As a result, these students' personalities tend to become stubborn, distrustful, lonely and rude due to the lack of family care, as well as psychological problems such as anxiety, loneliness and boredom caused by adjusting to their environment. As can be observed, students in boarding schools, as a special group, not only have the general psychological characteristics of contemporary students, but also have the special psychological issues of left-behind children.
- Typicality of teaching management mode. Due to the limitations of location, finance, and other conditions, boarding schools not only have a high boarding rate compared with urban ordinary schools, but also have the characteristics of poor teaching environment and quality (Li, 2018). For example, the all-day campus supervision has increased the burden of teachers and led to their neglect of student groups.

Based on the principles above, this study roughly evaluated whether the occurrence of outdoor school violence is enough to support the smooth development of the research through methods on students in different grades, such as random sampling and anonymous interviews. The survey eventually found that there was indeed a lot of outdoor violence in Case L, including fighting, speech isolation, abuse and so on. Consequently, the Case L was finally selected as the research object based on sufficient consideration of the significance and universality of the research results.

2.1.2 Current status

The Case L, a boarding school located in the southeast of Zhejiang Province, China, with students mainly coming from the 17 townships and 8 sub-districts within the county, has three grades with a total of 48 teaching classes and approximately 1,600 students. Meanwhile, the school covers an area of 101 acres with a building area of 57,000 square meters. As shown in **Fig. 2**, the school is divided into two areas by a river. The northern area contains teaching buildings, gymnasiums, canteen, male dormitories, outdoor sports ground, etc., and the southern area includes female dormitories and a parking lot. As a supplementary, the roads (represented by the letters A to T) and the main spatial nodes with actual photographs (represented by the Arabic numerals 1 to 20) all have been marked one by one. The figure also shows that the Case L has a playground, a square with gardens and several landscape nodes. And at present, the school has only one exit, which is located in the northeast of the basketball court and connects the road to the town.,

Figure 2: General plan of the Case L and actual photos of 20 spatial nodes.



2.2 Questionnaire investigation

2.2.1 Investigation method

In collaboration with teachers and students, this study used recess time to administer a questionnaire to a random questionnaire among young students aged 16-18 years old. The questionnaire consisted of three sections: personal basic information, outdoor school violence investigation, and current environmental evaluation, and the time for answering the questions was limited to 20 minutes. A total of 350 questionnaires were distributed and 342 questionnaires were returned, with a return rate of 97.71%. After screening and collating, 338 valid questionnaires were counted, resulting in the effective rate of 96.57%. Finally, SPSS19.0 was used to complete the data entry and obtain the sample basic data after statistical analysis.

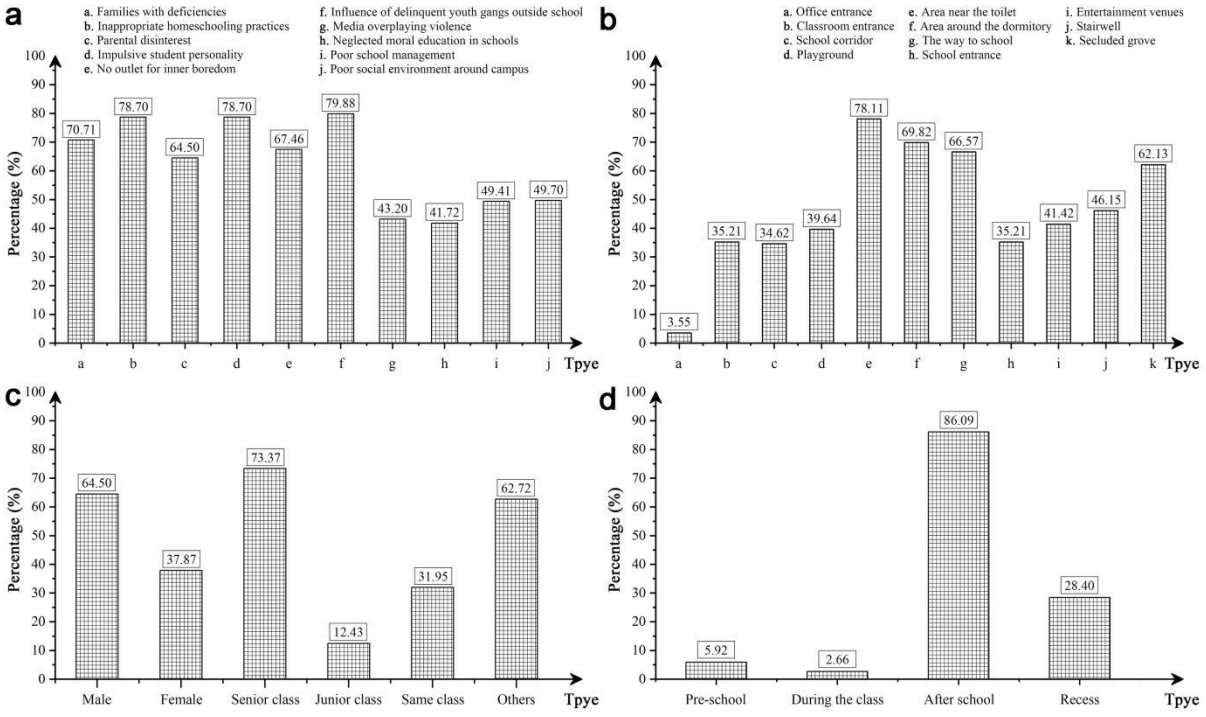
2.2.2 Evaluation analysis

The sample data showed that among the 338 students participating in the survey, 167 were male (49.41%) and 171 were female (50.59%). According to the source of students, the largest number of students came from rural areas, reaching 291 (86.09%), while the smallest number of students came from suburban areas, only 17 (5.03%), and 30 (8.88%) from urban

areas. And by the grade, 127, 160 and 51 students participated for sophomores, juniors and the seniors respectively, accounting for 37.57%, 47.34% and 15.09% correspondingly. Additionally, according to whether they were left-behind children or not, there were 87 left-behind students and 252 non-left-behind students, accounting for 25.74% and 74.56% respectively.

First of all, as illustrated in **Fig. 3**, the section “outdoor school violence investigation" revealed that inappropriate homeschooling practices, impulsive student personality and delinquent youth gangs outside school were cited as the main causes for outdoor school violence, with more than 78% of students believing these. At the same time, the areas near the toilet (78.11%), around the dormitory (69.82%), on the way to school (66.57%) and secluded groves (62.13%) were considered to be the places where most outdoor school violence occurs. As for males (64.50%), seniors (73.37%) were regarded as the most dominant perpetrators and most of the violence occurred after school (86.09%). Most importantly, 12.13% of the subject students indicated the existence of teacher violence and greater than 50% of the subject students stated that they had participated in, suffered or observed different types of outdoor school violence. In this study, the outdoor school violence was classified into four types, namely teacher-student conflict, verbal bullying, physical conflict, and extraneous invasive violence, as detailed in **Supplementary Tab. 1**. Among them, teacher-student conflict and verbal bullying were the most common violence behavior (the combined numbers of perpetrators and victims were 185 and 426 respectively), although physical conflict and intrusive violence were not as prevalent (the combined numbers of perpetrators and victims were 130 and 76 respectively), it’s also a strong sign of the seriousness for outdoor school violence for Case L.

Figure 3: Results of the outdoor school violence investigation. (a) causes; (b) locations; (c) types; (d) the occurrence time. N = 338, female 50.59%.



Secondly, the “current environmental evaluation” section showed that more than 20% of

the subject students felt that the school entrance was narrow and disorganized (29.00%) and the distance to sports venues was far away (20.12%). Meanwhile, more than 17% of the subject students believed that the current environment had visual blind spots in the landscape (19.23%), dim lighting design (17.16%), remote location of the dormitories (18.34%), lack of leisure facilities (17.46%) and more visual blind areas (18.94%). However, only about 6% of students were dissatisfied with the campus landscape management and garbage cleaning. As a complement, student satisfaction evaluation for other related issues, such as the campus fence height and building planning, are also available in **Supplementary Tab. 2**.

Finally, with the above data and the general plan of the outdoor violence locations depicted by the subject students, this study used Arc GIS to mark each area of the campus based on the violence occurrence and to create the distribution maps of outdoor school violence in Case L.

2.3 Spatial simulation

In this study, the depthmapX software, a basic tool of Spatial Syntax theory, was used to analyse the SOE of Case L. And this software, dedicated to urban spatial analysis, mainly contains three basic analysis models, namely Axis model, Convex Space Analysis (CSA) model and Visibility Graph Analysis (VGA) model (Hillier & Hanson, 1984), which can be used to calculate parameters such as integration (Int), choice and visibility. In order to conduct a comprehensive public safety assessment, the Axis model and VGA model were applied in this study to analyze the relevant parameters of the spatial characteristics of the SOE, mainly described as following.

- Int represents the relationship between a space and local or overall space, that is, the accessibility of the space. The higher the Int value, the higher the accessibility (Summers & Johnson, 2017).
- Mean Depth (MD) indicates the number of transformations from local space to other parts of space, representing the convenience of the node in the spatial system. Higher MD values indicate higher spatial separation (Hillier, 1996).
- Connectivity (Conn) refers to the sum of the number of spaces directly connected with the surrounding space. The higher the Conn value of a space, the more spaces connected with it, characterizing as a transportation hub in the spatial system.
- Control (Cont) denotes the control strength of the connection between spaces. The greater the Cont value, the stronger the dependence of other nodes in the space on it (Hillier & Hanson, 1984).
- Intelligibility reflects the difficulty of finding a way in the environment,that is, the ease of teachers and students from any position to another position in the whole space system (Hillier, 1996).
- Visibility Connectivity (VC) shows the number of other points that a point can see within its line of sight, reflecting the quality of natural surveillance provided by the outdoor environment to users or passers-by. The higher the value of VC, the better the quality of surveillance or under surveillance (Aziz, 2020).

It can be concluded that these parameters mentioned above are closely linked to the accessibility and visibility of the space. And specific numerical range in the final analysis results of each parameter is represented as a colour scale from cold (dark blue) to warm (deep red), with the former indicating low values and the latter indicating high values.

However, particular attention needs to be paid to the calculation method of tree elements in software simulation, as the effects of canopy size and density on spatial visibility and accessibility are complex (Mingyun et al., 2018). On the one hand, the trunk height may affect the results of spatial analysis. Specifically, trees with high trunks won't affect people's sight and behaviour, but trees with low trunks (especially shrubs) may impede people's passage. On the other hand, heavy foliage can obscure views, while sparse foliage provides a degree of visual connectivity compared to buildings. Consequently, as illustrated in **Tab. 2**, this study classified possible obstructions such as trees and street furniture in schools. For the first, shrubs and small trees with large canopies and low trunks were considered as obstacles in visibility analysis. And secondly, large trees with high trunks or small canopies, as well as low shrubs, resting seats, street lamps and other street furniture, were all considered as negligible obstacles. Thirdly, motor vehicle parking was regarded as obstacles in accessibility and visibility analysis. In addition, considering that tree canopy changes in different seasons may have an impact on the spatial analysis results, two seasons with large differences, summer and winter, were chosen for this study in order to obtain more accurate and comprehensive analysis results.

Table 2: The calculation method of various elements in the process of spatial syntax simulation.

Object	**Type**	**Trunk height**	**Canopy size**	**Opacity in summer**	**Opacity in winter**
Cinnamomum camphora	Evergreen tree	Medium	Large	High	High
Ligustrum lucidum	Evergreen tree	High	Large	Low	Low
Ginkgo biloba	Deciduous tree	Medium	Small	High	Low
Metasequoia	Deciduous tree	Medium	Small	High	Low
Osmanthus fragrans	Evergreen tree	Medium	Medium	High	High
Magnolia grandiflora	Evergreen tree	High	Large	Low	Low
Camellia japonica L.	Evergreen tree	Low	Medium	High	High
Liquidambar formosana Hance	Deciduous tree	Low	Medium	High	Low
Liriodendron chinense	Deciduous tree	High	Large	Low	Low
Punica granatum L.	Deciduous tree	Low	Medium	High	Low
Prunus serrulata	Deciduous tree	Low	Medium	High	Low
Sapindus	Deciduous tree	High	Large	Low	Low
Basketball hoop	Sporting facility	/	/	Low	Low
Football rack	Sporting facility	/	/	Low	Low
Street light	Infrastructure	/	/	Low	Low
Rubbish bin	Infrastructure	/	/	Low	Low
Outdoor seat	Infrastructure	/	/	Low	Low
Parked car	Infrastructure	/	/	High	High

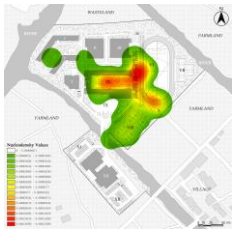
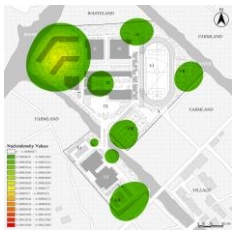
3. Results and Discussion

3.1 Violence occurrence distribution map

As presented in **Tab. 3**, the analysis results of the outdoor school violence indicated that verbal bullying, such as insulting nicknames and verbal threats, was most common in Case L, which was widespread in the vast majority of the outdoor spaces and concentrated in the two

dormitory areas and the internal courtyard of the teaching building. Next, student-teacher conflict, including cynicism and corporal punishment, occurred mainly in the courtyard of the teaching building, to a lesser extent, in spaces such as the male dormitory area, the playground and the school entrance. Then there were the more serious incidents of physical conflict, with the highest proportion of kicking and punching, followed by fighting and brawling. These incidents occurred mostly on the northern boundary of the campus, the southern side of the male dormitory area and the southern car park around female dormitory. The extraneous invasive violence, which was closely related to the external space of the campus, occurred mainly in the woods around the volleyball court, the western of the male dormitory area and the periphery of the female dormitory area, including acts of intimidation and threats, extortion of property, etc. It is worth noting that the reasons for these results correspond to the current situation evaluation results, such as “No wall or too low walls in school” and “Visual blind spots in landscape space”.

Table 3: Occurrence and distribution maps of four types of outdoor violence in Case L.

Violence types	**Violence activities**	**Number**	**Total Percentage (%)**	**Violence occurrence map**
Teacher-student conflict	Cynicism	93	22.64	
	Corporal punishment	92		
Verbal bullying	Insulting nickname	98	52.14	
	Isolating others	90		
	Ridiculing others for the incompatibility of their personality with their gender	44		
	Deliberately pushing others	42		
	Verbal threat	64		
	Refusing others to participate in collective activities	39		
	Reject people of the same gender or opposite gender	49		
Physical conflict	Kicking and beating others	89	15.92	
	Fighting	41		
Extraneous invasive violence	Intimidation and threat	36	9.30	
	Blackmailing	29		

	Affray	11

On the whole, the outdoor violence of Case L mainly occurred in the peripheral areas, around the two dormitory areas and the internal courtyards of the teaching building. And the areas around the outdoor sports venues, canteen and gymnasium were also violent but infrequent, while the central area of the school (the administration building) was relatively safe and almost free of violence.

3.2 Spatial configurations analysis

By using depthmapX software with Spatial Syntax theory, this study depicted the boundary lines of walkable areas such as roads, squares and outdoor sports venues, and established an Axis model of the SOE for Case L. On this basis, the four parameters, including Int, MD, Conn and Cont, were simulated and analyzed, and the specific values were presented in **Tab. 4**.

Table 4: Results of spatial configuration parameters of SOE in Case L.

Numeric type	**Int**	**MD**	**Conn**	**Cont**
Average	6.00	2.88	687.29	0.26
Minimum	1.58	1.95	4.00	0.02
Maximum	10.17	7.15	1,833.00	0.68
Standard deviation	1.96	0.91	575.61	0.13

3.2.1 Int graph

Fig. 4 displays the results of the Int of the walkable layer of the SOE, which shows that the color of playground, the volleyball court and the roads F, H, I, L and N connecting them was the warmest, especially playground centre, roads H, I and other intersections, indicating that these spaces were the most integrated. And the basketball court, the south square, the internal courtyard and the roads B, C, D, K, M and O connecting them were painted in neutral colour. The courtyards and roads A, J between the male dormitories, the school entrance road P and the roads Q, R, S, T around the female dormitories had the coolest colour, indicating that the Int values of these spaces were the lowest. The spatial colour distribution of the SOE shows a change from warm to cool from the playground to the two dormitory areas and the internal courtyard, reflecting the change in Int value from high to low. Furthermore, **Fig. 5** represents the Int value deviation. It's clear that half of the spatial Int was close to the mean while the other half exhibited a significant polarization, indicating that there were a certain number of spaces with low Int in the Case L. Relevant studies have shown that the higher Int means the better spatial accessibility, the stronger publicity, and the easier for people to gather (Curtis, 2012). In other words, according to the CPTED theory, it may result in stronger natural surveillance for spatial environment, which will be conducive to crime prevention. Thus, in Case L, the spatial nodes 2, 3, 8 and roads A, J, Q, R, S, T that with low Int values were highly vulnerable to violence due to weak accessibility, while the playground, volleyball court and the roads connecting them avoid violence because of their strong accessibility.

Figure 4: Int graph exported from depthmapX software.

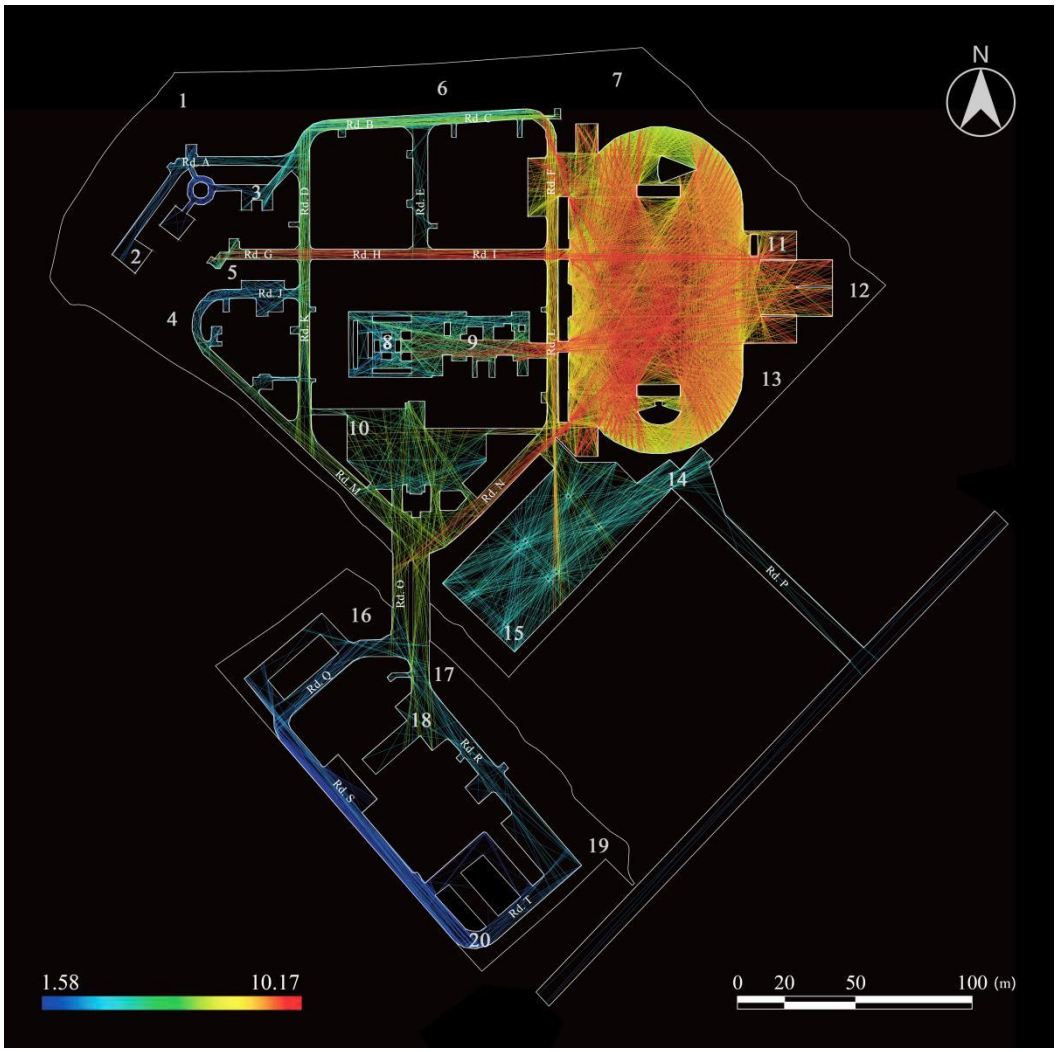
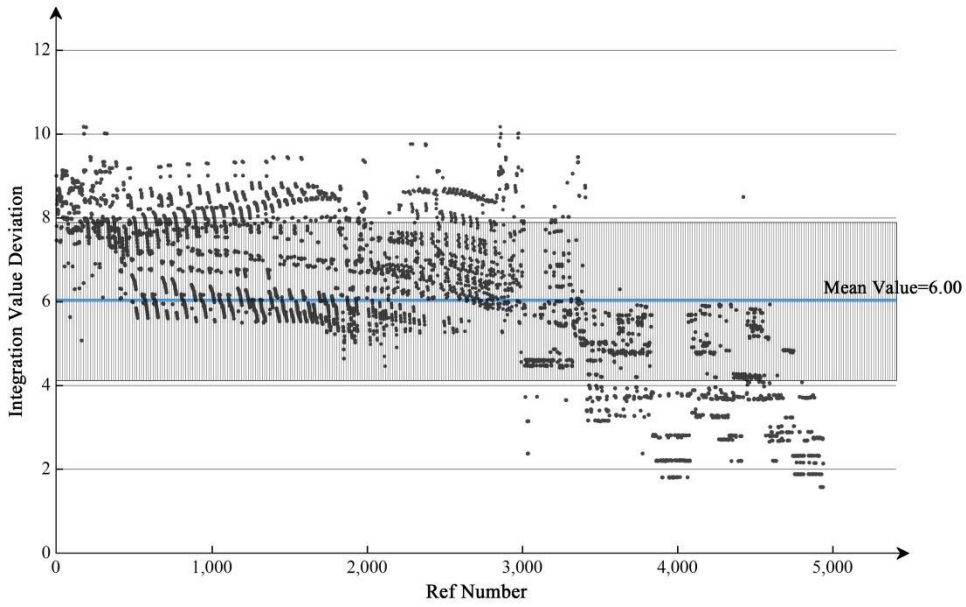


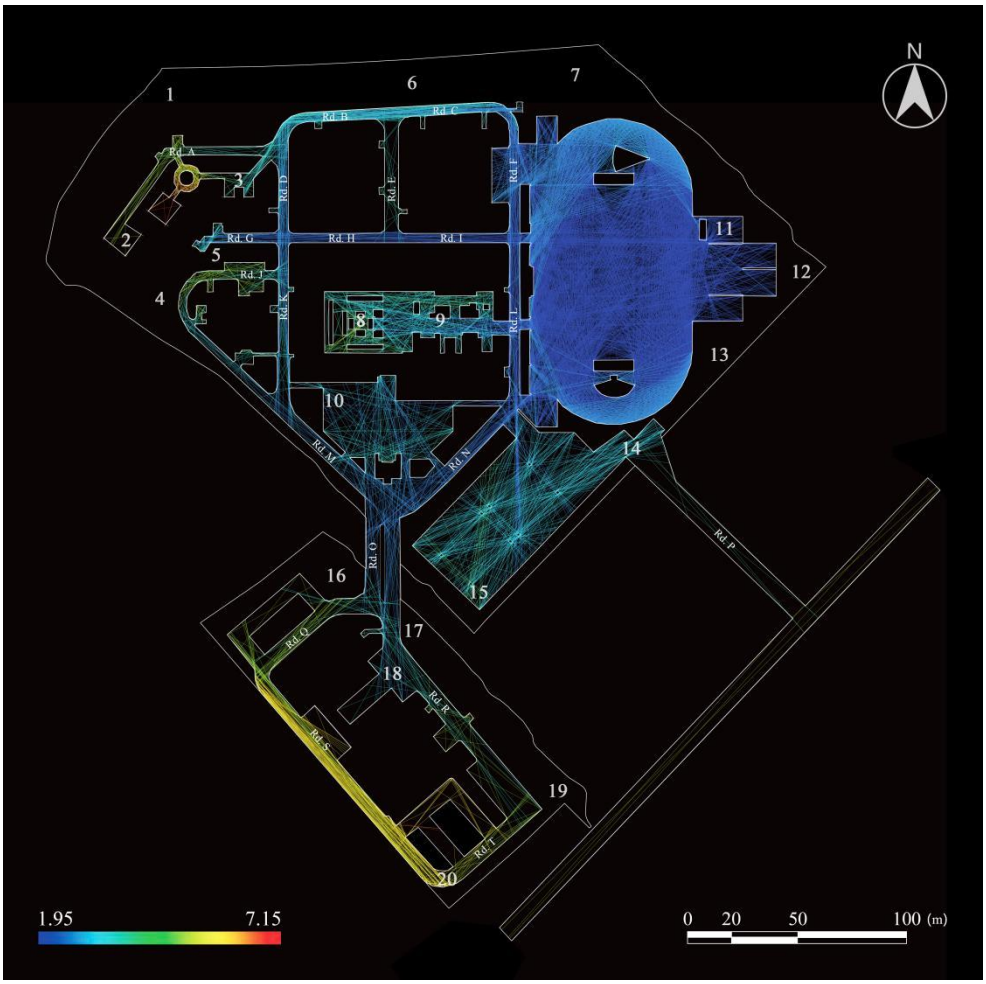
Figure 5: Deviation distribution of Int values.



3.2.2 MD graph

MD values displayed in **Fig. 6** shows that the courtyards around the male dormitories (nodes 2 and 3) and the roads Q, S, T around the female dormitories had the warmest colour, illustrating that these spaces had the greatest depth values. Concretely, it's relatively difficult for people to reach the two areas, which were highly segregated. But the color of the playground, volleyball court and the roads D, F, G, H, I, K, L, N, O connecting them reached the coldest, meaning that these spaces had the lowest depth values and were easily accessible to people. At the same time, the roads A, B, C, E, J, M, P, R connecting the two space types above, the south square, the basketball court, the internal courtyard and the school entrance were shown in neutral colour, indicating that the MD values of these areas were at a medium level. It can be seen that, the two dormitory areas (nodes 2, 3, 20 and roads Q, S, T) and the internal courtyard (node 8) were spaces with high MD values, which implies that they were provided with relatively blocked traffic, poorly accessibility and weakly natural surveillance, and were potential spaces for violence occurrence in Case L.

Figure 6: MD graph exported from depthmapX software.

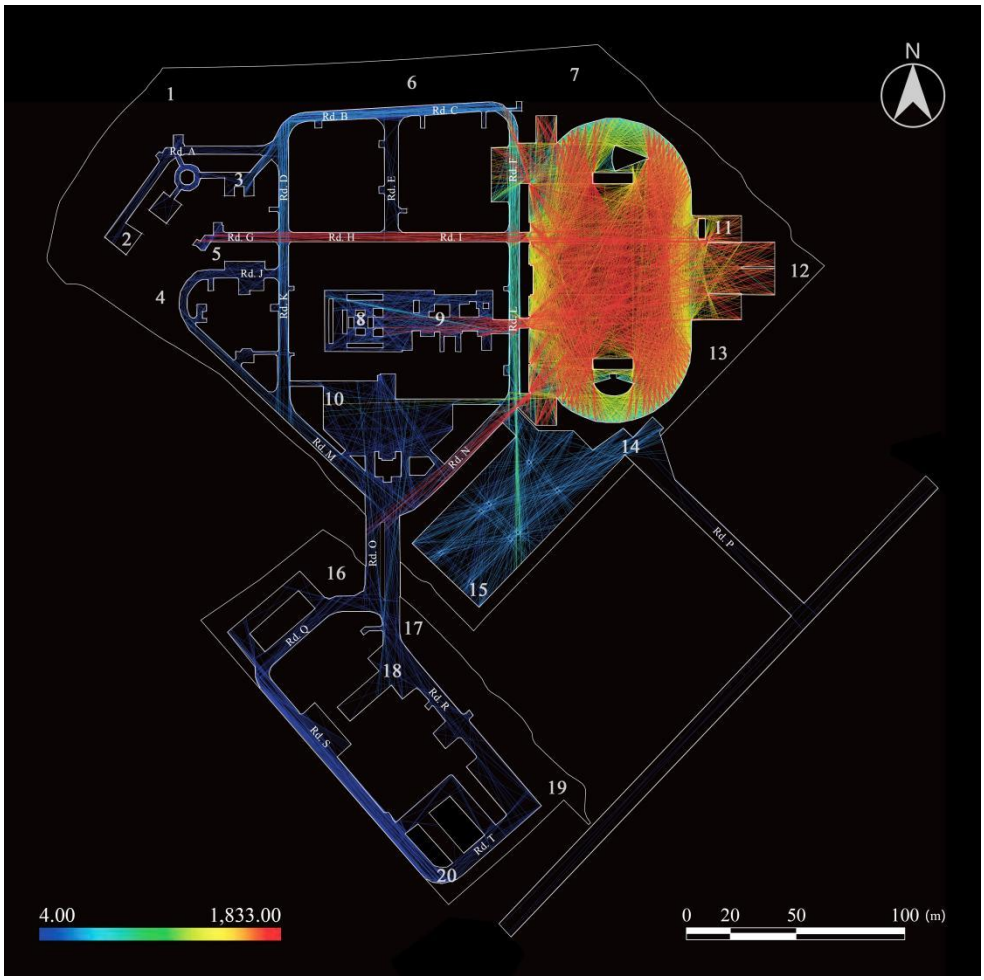


3.2.3 Conn graph

Fig. 7 illustrates the results of the Conn analysis for the walkable layer in Case L. The spatial color of the playground, the volleyball court and the roads G, H, I, N was the warmest, especially in the playground centre and road I. Meanwhile, high levels of Conn also occurred at the intersections, such as the intersection of the internal courtyard with road L, which

means that the above spaces had significantly high Conn values and were important traffic hubs in the whole SOE. Secondly, only the spatial color of roads F and L was neutral, indicating that there were fewer spaces with average Conn values. In addition, the rest of the spaces other than the above were painted in cooler colour, including the two dormitory areas, the basketball court, the south square and internal courtyard, etc., showing that the Conn values of these spaces were significantly low. Overall, the Conn values for the Case L present a clear polarization, similar to the results of the Int graph. In detail, the spaces with high Conn values, including the playground, volleyball court and major intersections, also had relatively high Int values, signifying that these spaces had a stronger influence on the surrounding spaces and better spatial permeability.

Figure 7: Conn graph exported from depthmapX software.

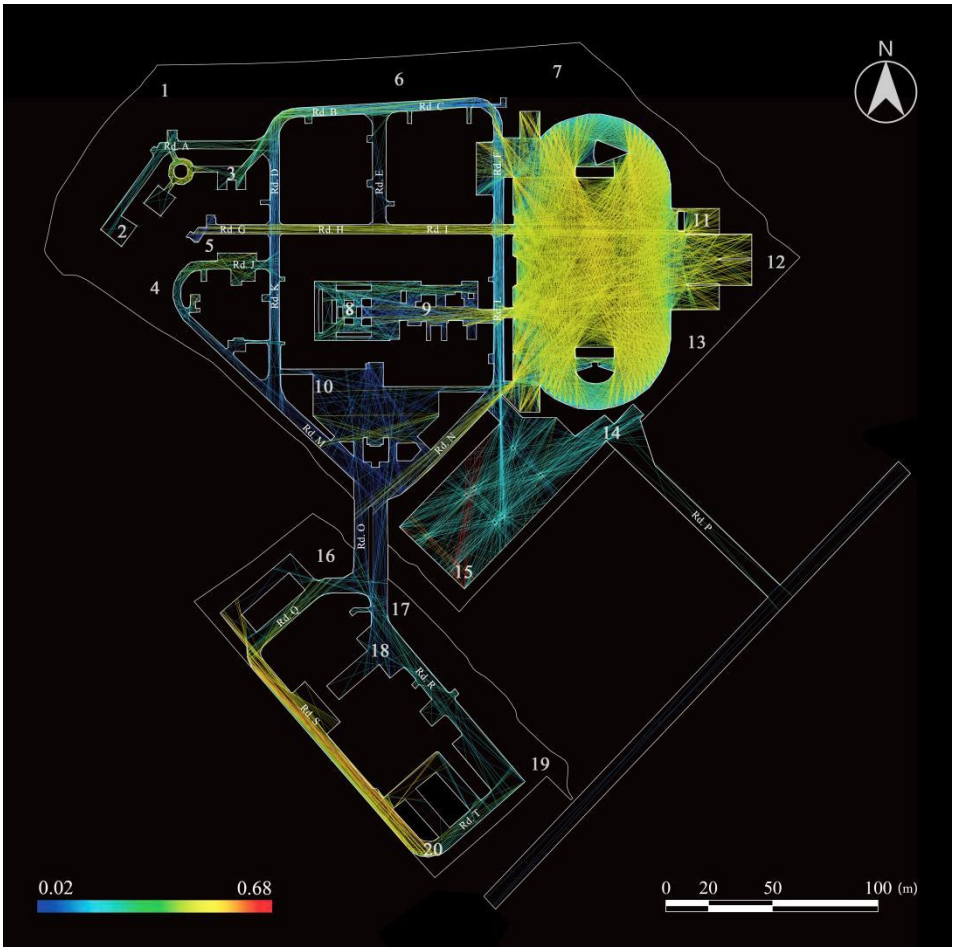


3.2.4 Cont graph

The spatial Cont graph, **Fig. 8**, presents that the spatial colour of most areas in Case L was neutral or cooler, meaning that the overall Cont was low. Among them, the south square, the internal courtyard and the roads D, F, K, L, M, O, P connecting them had the coolest spatial colour, indicating that they had the lowest Cont values over the surroundings. And some main roads A, B, C, E, J, Q, R, T, the basketball court and the school entrance were neutral in colour. It's noteworthy that the school entrance (node 14) didn't reach a high Cont value in the overall environment, suggesting that the surroundings were not strongly dependent on it and that it couldn't play an ideal role of access control. This corresponds to

the results of the current environmental evaluation where the subject students perceived that the school entrance was in disorder. Then the playground and its connected roads G, H, I, N, the courtyards around the male dormitories (nodes 2 and 3) and the road S were relatively warm in colour, especially the playground centre and the intersections of main roads were the warmest, which implies that these spaces had higher Cont values over the surroundings. By improving the Int values of these spaces, therefore, the overall Int of the surrounding spaces can all be largely optimized (Zhao, 2013).

Figure 8: Cont graph exported from depthmapX software.

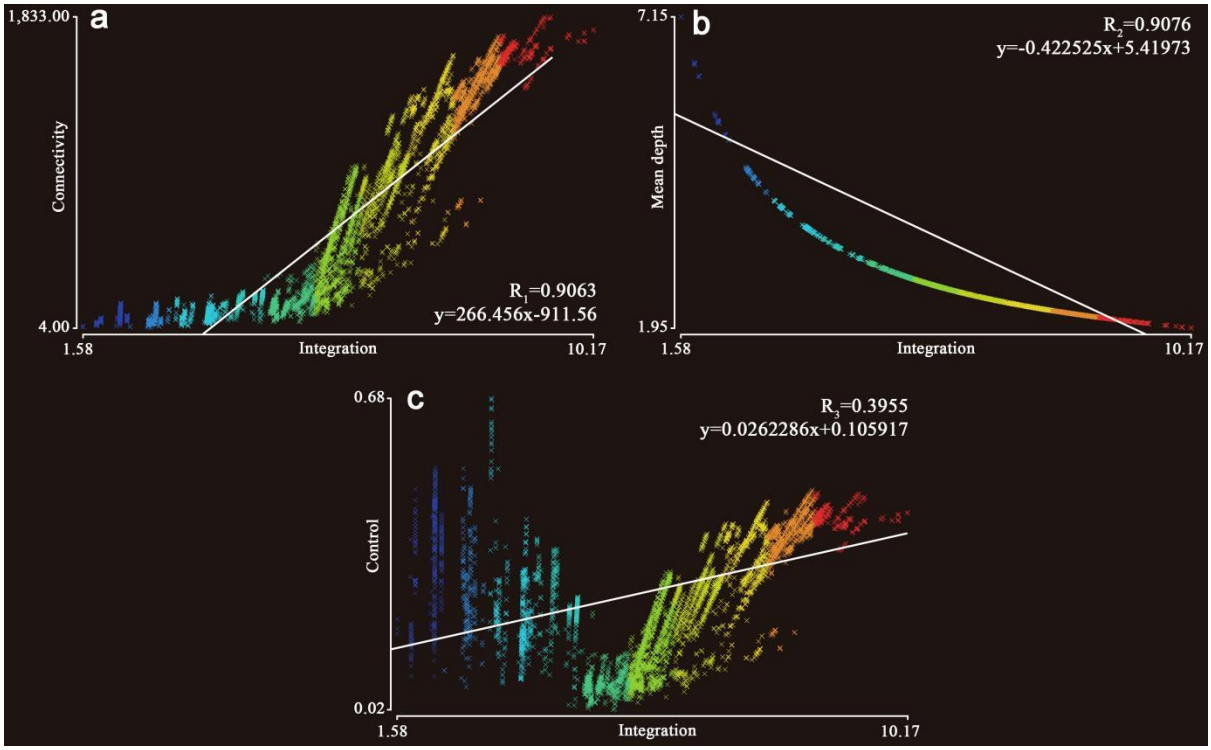


3.2.5 Intelligibility graph

The spatial Intelligibility was also calculated in this study, which is a variable to measure the correlation between local variables and entire variables. Previous research (Hillier, 1996) has demonstrated that the higher intelligibility value the space reaches, the more its local centrality can be integrated into the overall space to enhance the diversity and complexity. And **Fig. 9** shows the fitted relationship functions between the Int and the three variables, including MD, Conn and Cont ($R < 0.5$, no correlation; $0.5 \leq R < 0.7$, weak correlation; $0.7 \leq R < 0.9$, a little strong correlation; $0.9 \leq R < 1.0$, strong correlation). Then the results point that the R_1 between Int and Conn was 0.9063, implying that spaces with better Int value also had better Conn. And there is a negative correlation between Int and MD with R_2 of 0.9076, which indicates that the spaces with higher Int values tend to have lower MD values. Nevertheless, it's found that the R_3 between Int and Cont was only 0.3955, indicating that there was no significant correlation between them. In combination, the spaces

and paths, which met high levels of Int and Conn but low MD values, were considered as the parts with better intelligibility in the whole SOE. In other terms, the playground, the volleyball court and the intersections of main roads were the local spaces with higher intelligibility values of the SOE in Case L.

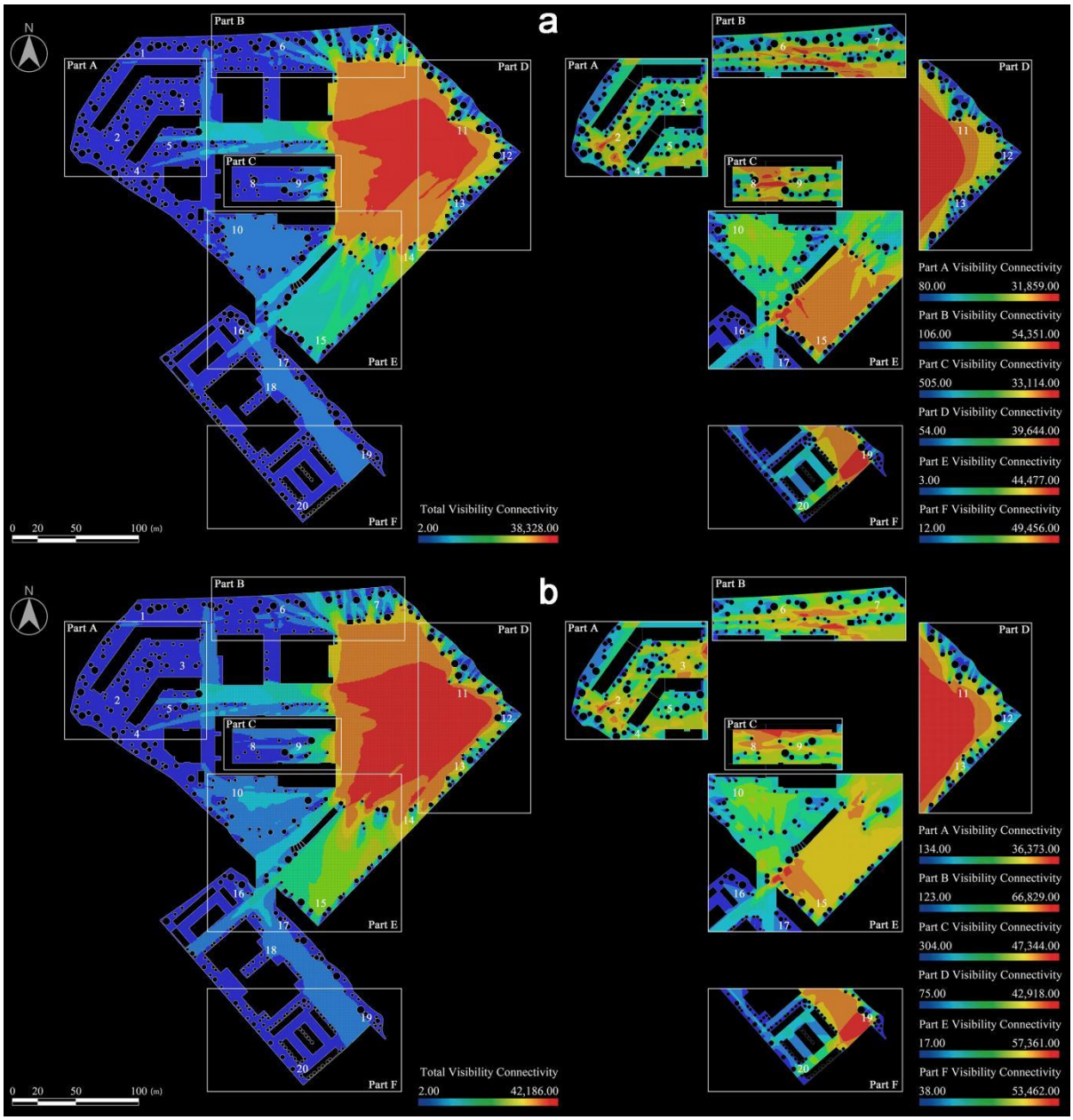
Figure 9: Intelligibility graphs exported from depthmapX software. (a) the scatter graph of Int and Conn; (b) the scatter graph of Int and MD; (c) the scatter graph of Int and Cont.



3.3 Spatial visibility graph analysis

In the spatial visibility simulation, this study created the VGA model for the visibility of the SOE by mapping the boundaries of school fences, buildings, plant canopies and different street furniture. It should be mentioned that the different paved roads and lawn areas were treated without distinction while parking spaces were considered to be full of vehicles, meaning that they were counted as an obstruction to sight. Moreover, in complement to the total VC, six local VC were also calculated in this study. Combined with the above points, the results of VC for outdoor environment in summer and winter scenarios are shown in **Fig. 10**.

Figure 10: VC graphs exported from depthmapX software. (a) Summer scenario; (b)Winter scenario.



The results demonstrate that the total visibility remains strongly consistent in both summer and winter. Firstly, the volleyball court, the playground, the road F and L all showed good VC due to the space openness, particularly volleyball court centre where the spatial colour was the warmest, while the colour in the peripheral areas of the playground (nodes 7, 11, 12 and 13) tended towards neutral or cold. It implies a radial distribution VC in the outdoor sports area, with the central area was the most visible and the boundary areas were the least visible. Secondly, the spaces to the west of the teaching building (roads G, H and I) and the basketball court reached a neutral colour with average VC values. Thirdly, the internal courtyard, the male dormitory area, the parking lot in the female dormitory area and the associated spaces (roads Q, S and T) had the coolest colour, so considered to be the local spaces with relatively poor visibility.

Intriguingly, through comparative analysis on the local VC in two season scenarios, it

can be found that the spatial visibility of the SOE was greatly negatively affected by deciduous trees, especially the trees with medium-sized canopies, such as Cinnamomum camphora, Osmanthus fragrans, and Camellia japonica L.. Specifically, the impact was more pronounced in summer than in winter, as evidenced by the fact that the area of high visibility in summer was significantly smaller in summer than in winter. Additionally, due to the seasonal influence of deciduous trees, the VC values of some spatial nodes 3, 8, 10 and 13 in winter was higher than that in summer. As can be seen, therefore, the visual bind spaces created by the building outlines, as well as the plant communities, made some spaces (nodes 1, 4, 8, 12, 13, 16, 17, 19 and 20) more obscured, leading to a neglect of the maintenance of the environment image.

3.4 The relevance of spatial characteristics to violence occurrence

ArcGIS software was used to interpolate the simulation results of SOE. Twenty representative spatial nodes (see **Fig. 2** for details) were selected as samples, and the six spatial parameters and violence occurrences for these samples were collated. See **Supplementary Tab. 3** for details. Based on these sample data, this study examined the correlation between the spatial characteristics of the SOE and the outdoor violence occurrence in terms of both spatial configurations and spatial visibility. And the parameter value ranges for different types of outdoor violence are listed in **Tab. 5**.

Table 5: Parameter distribution of the occurrence area for each type of outdoor violence in Case L.

Violence type areas	**Int**	**MD**	**Conn**	**Cont**	**VCs**	**VCw**
Teacher-student conflict	2.14-8.84	2.06-5.53	10.00-941.00	0.05-0.68	612.00-28,701.00	1219.00-33,048.00
Verbal bullying	1.58-9.13	2.04-6.37	11.00-1,774.00	0.04-0.68	628.00-30,259.00	937.00-36,217.00
Physical conflict	1.79-4.27	3.16-7.15	4.00-208.00	0.06-0.53	122.00-15,811.00	211.00-34,127.00
Extraneous invasive violence	N/A	N/A	N/A	N/A	97.00-6,218.00	194.00-34,007.00
No-violence area	1.79-10.17	1.95-4.09	11.00-1,833.00	0.02-0.68	628.00-38,328.00	956.00-42,186.00

3.4.1 Spatial configurations to violence types and distribution

The research pointed out that there was a relationship between the distribution of outdoor violence types and specific spatial configurations in boarding schools, mainly in Int, MD and Conn, but with no significant relationship to Cont. For example, firstly, the walkable layer areas (nodes 9, 10, 11 and 18), with low MD values but high Int and Conn values, had relatively few records of violence mostly with less harm, such as verbal bullying including insulting nicknames. Secondly, in the walkable or non-walkable layer areas (nodes 2, 3, 8 and 20), where the MD was greater but the Int and Conn values were lower, some of outdoor violence incidents with serious harm may easily occur, such as punching others and other physical conflicts. Meanwhile, most of these incidents occurred in areas like the courtyards in the dormitory areas (nodes 2 and 3), rather than campus roads, outdoor sports grounds, or squares. Thirdly, external intrusive violence tended to occur in the non-walkable layer areas (nodes 1, 7, 12, 13 and 19), as this kind of areas closed to campus boundary often offer the maximum potential for external perpetrators to invade and escape. Coincidentally, the fieldwork and the current environmental evaluation together indicated that there were indeed shortcuts created by human trampling in some non-walkable layer areas, providing pathways

for perpetrators to commit violence. Furthermore, the school fences of some spatial nodes 12 and 13 were not set or set too low, resulting in more extraneous invasive violence here. Fourthly, in contrast, the teacher-student conflicts occurred mostly in areas around the teaching building and the school entrance, mainly depending on the characteristics of teachers' activities. Although this violence type failed to be associated with spatial configurations, but related to the campus functional configurations.

Tab. 5 shows the values of each parameter for the different types of outdoor school violence areas. As a detail, excluding the teacher-student conflict areas and external intrusive violence areas, relatively speaking, the no-violence areas may had higher Int values (up to 10.17), lower MD values (up to 1.95) and higher Conn values (up to 1,833.00), while the physical conflict areas reached lower Int values (up to 1.79), higher MD values (up to 7.15), and lower Conn values (up to 208.00).

3.4.2 Spatial visibility to violence types and distribution

Through the comparative analysis of **Fig. 2**, **Tab. 3** and **Fig. 10**, the research also found a correlation between the spatial visibility of the SOE and the distribution of each type of outdoor violence in boarding schools. Specifically, the areas with higher VC values, for instance the centre of outdoor sports grounds, were relatively less likely to experience serious harmful outdoor violence. Moreover, in the school peripheral areas, which were densely planted with vegetation (especially evergreen trees), serious harmful incidents usually occurred here, such as fights and brawls, because of the poorly spatial visibility.

Among the different types of outdoor school violence, the extraneous invasive violence such as mob fights, occurred in the boundary areas of the two dormitories and the volleyball court (nodes 1, 4, 7, 12, 13, 19 and 20), where the VC values were the lowest due to the building outlines or the dense vegetation. And the areas with average or greater visibility (nodes 6, 9, 10, 11, 14, 15, 18) were relatively prone to slight harmful violence, such as insulting nicknames, verbal threats and so on, since these spaces tended to be more crowded, making it easier for perpetrators to hide. The physical conflict mostly occurred in the areas with average and poorer visibility (nodes 1, 2, 3, 4, 5, 6, 8, 12, 13, 16, 17, 19 and 20), with a small number occurring in areas of greater visibility (volleyball and basketball courts), which was related to the causes of violence. Nevertheless, the teacher-student conflict was often concentrated around the teaching building, but has no clear relationship with spatial visibility. The VC values in summer and winter scenarios for each violence occurrence area were summarized in **Tab. 5**. It can be seen that the values for no-violence areas were relatively higher (up to 38,328.00 in summer and 42,186.00 in winter), while that for external intrusive violence and physical conflict behaviour were lower (down to 97.00 and 122.00 in summer, with down to 194.00 and 211.00 in winter respectively).

In summary, the spatial configurations of SOE had an impact on the distribution of outdoor violence types. For example, the areas with low Int and Conn but high MD, such as the two dormitory areas and the internal courtyard, contributed to the outdoor violence occurrence. Additionally, although rich and large-area of green vegetation may bring a pleasant atmosphere and healthy environment, it also caused potential hazards. So some areas, where the opacity of the tree canopy greatly reduced the spatial visibility, provided a great opportunity for outdoor violence to occur, particularly in the peripheral areas. Notably, however, of the four violence types in boarding school, only the teacher-student conflict was

not clearly correlated with spatial characteristics, but its distribution was linked to the scope of teachers' activities and the functional configurations, as these violence usually occurred around teaching building, school entrance and sports grounds.

3.5 Violent space classification with optimal design

In addition to exploring the correlation between the outdoor violence occurrence and the spatial characteristics of the SOE, this study further classified the occurrence spaces of various violence types in terms of spatial configurations and spatial visibility. Four space types, namely violent hidden space, violent motivated space, violent detracted space, and violent facilitated space, were proposed, and targeted environmental design strategies were also suggested for them.

3.5.1 Violent hidden space

Violent hidden space refers to the area with average or greater spatial configuration and visibility, and located within the walkable layer. Due to sound spatial characteristics, such space is often that with dense crowd, such as the south square and outdoor sports grounds, which provides hiding opportunities for people who have uncertain violence motives but may commit violence. As a result, it tends to be no-violence, or only partially harmed by less harmful verbal bullying, including verbal abuse and pushing others. For violent hidden space, social prevention means such as enhancing security patrols at the spaces with relatively higher Cont values, and setting up electronic surveillance in crowded places will become important to prevent outdoor violence by strengthening human surveillance to restrain the behaviour and motivation of potential perpetrators (Kweon, 2016). Furthermore, for the space with the high degree of Int but low MD, such as the school entrance, in order to control the flow of people and enhance the retention of the space, it's feasible and effective to enriched through adding landscape features and reasonably set up security facilities (Steventon, 1996), with appropriately increasing the MD values and improving natural surveillance.

3.5.2 Violent motivated space

Within the walkable layer, the area has poor spatial configuration and visibility is defined as Violent motivated space, including the roads end of the walkable layer, narrow courtyards, and other hidden spaces. And because of the sparse pedestrian traffic as well as the sheltering of the buildings and the vegetation, the violent motivated space often has poorly natural surveillance and less support for activities, thus provoking students to commit violence. Consequently, this kind of space is relatively prone to physical conflicts with slightly serious harm, such as kicking and punching others, as well as a certain number of verbal bullying incidents. But in fact, to create a quiet and comfortable SOE, violent motivated space is often unavoidable due to building outlines and plantings.

Based on the territoriality and activity support of CPTED theory, modest activity implantation in these spaces, such as adding activity venues, landscape vignettes, resting seats and organizing outdoor activities for students (Steventon, 1996), thereby attracts people to come and conduct communication activities and enhance the sense of belonging. At the same time, the spatial image should be well maintained, including the selection of tree species with shrubs of a height below the average height of students' eyesight, and trees with higher trunks and small-sized canopies, such as Ginkgo biloba and Magnolia grandiflora. Through the strategies mentioned above, the lack of natural surveillance in the violent motivated space can be compensated for as much as possible, while satisfying certain

ornament and comfort, and inhibiting the occurrence of outdoor violence.

3.5.3 Violent detracted space

The area with average visibility but located outside the walkable layer is defined as violent detracted space. Despite having the relatively greater visibility, this type of space is less frequented with poor territoriality and scarcity activity support, since it belongs to the non-walkable layer. It therefore becomes a place where violence can be committed by potential perpetrators and where physical conflict such as fights is more likely to take place. Based on the fieldwork, there were indeed many man-made stampeded shortcuts and depressions near the peripheral fences in the dormitory areas of Case L, which may be the main places for the perpetrators to commit violence or escape from the scene. For the violent detracted space, increasing the planting of low shrubs and building facilities can be effective in reducing the "shortcuts" of perpetrators and introducing student activities to create territoriality. At the same time, regular landscape restoration and optimization can help to prevent further damage to the environment and enhance the the environmental image, thereby facilitating crime prevention (Atlas, 2013; Alsharif et al., 2020). Moreover, it's also necessary to strengthen the surveillance, in combination with the rational allocation, electronic surveillance and other facilities.

3.5.4 Violent facilitated space

Violent facilitated space refers to the area located the non-walkable layer and with poor visibility, which is usually found in the school peripheral areas. Due to the poor visibility from the overgrown vegetation and hard to access, this space is characterized with lacking in activity support and environmental maintenance, providing hidden pathways for the occurrence of outdoor violence on and off. In other words, the violent facilitated space creates a place for external perpetrators to enter and carry out school violence such as intimidation and threatening and mobbing, thus making it more prone to the serious harmful extraneous invasive violence.

According to the CPTED elements, for the violence prevention, on the one hand, it's also essential to optimize the landscape design and image maintenance, and on the other hand, it's also essential to reduce the eyesight shading by regularly trimming or planting trees with high trunk, so that extraneous perpetrators cannot invade and are difficult to hide. To complement these, warning signs, safety information boards and landscaping vignettes need to be installed to increase the attention of students and enhance the natural surveillance (Cowie, 2011). And in order to compensate for the poor visibility, improving lighting at night and adding surveillance equipment are also necessary to help campus security staffs detect suspected or potential violence (Xu, 2002), upgrading public safety in the whole SOE.

3.6 Limitations

Firstly, to guarantee the integrity and credibility of the overall logic of the study, only one case school was selected as the sample for this study. Thus, although Case L is representative in school management system and the occurrence of school violence, it still cannot show the specific situation of school violence in China or all over the world. What's more, the occurrence of school violence in different areas would be influenced by the surrounding environment, and there are differences between each violent incident, which requires further research to justify.

Secondly, this study plotted the distribution maps of outdoor school violence by marking

the locations of violence on the general plan, which was not a fully accurate method of counting relied on student memory, with data subject to error. Nevertheless, this can still be a positive help in determining the general area where outdoor violence occurs in schools.

Finally, there are numerous difficulties when using the depthmapX software for simulation. On the one side, there are no clear physical boundaries such as walls in outdoor environment compared indoor environment, so the spatial configurations analysis in this study classified the lawn as an inactive area, although people can step on it. On the other side, since the software is a two-dimensional running environment, it does not yet support the analysis of factors influencing the three-dimensional space such as tree height and canopy size. Therefore, for the spatial visibility analysis, this study categorized possible obstacles in the SOE in order to get as close to the real results as possible, but ignored the impact of road material, environmental color, and other factors on the occurrence of violence (Tomita et al., 2003; Braun et al., 1994).

4. Conclusion

The CPTED theory has been developed for approximately fifty years, during which its core elements have been continuously improved and expanded, and has made a significant contribution to the security research and practice in many fields, including urban residential areas, sub-districts, parks and so on. As a link between the spatial characteristics of urban environment and the behaviour of human activities, the Spatial Syntax theory has also been developed for more than twenty years, and has gradually become an important tool for the research of the correlation between criminal behaviour and spatial characteristics. Set in China, where boarding schools account for a high proportion, as the research background, this study selected the Case L in the southeast of Zhejiang Province as the object, and comprehensively used CPTED and Spatial Syntax tools to explore the impact of spatial characteristics of the SOE on the violence types and distribution.

Firstly, the study pointed out that the Int, MD and Conn in spatial configurations were correlated with the distribution of outdoor violence types. For example, the space inside the walkable layer, with greater Int and Conn but low MD, can attract people to gather, and is basically no-violence or only less harmful verbal bullying occurs. And the walkable layer space with low Int and Conn but high average depth is prone to physical conflict such as kicking and punching others. The relatively more extraneous invasive violence with serious harm tends to occur in walkable layer space, while teacher-student conflict don’t correlate significantly with spatial configurations, but linked to the school functional configurations. The configuration analysis results in this paper verify the view of Ju Mi-OK and Lee Chang Hun that more and more serious violence incidents occur in the space with poor accessibility such as the peripheral areas of the SOE (Changhun, 2017). Another study conducted by Wang Shanshan in Guangzhou, China also showed that school entrance area with high Int may also have a higher possibility of violence due to poor access control (Wang, 2017). Nevertheless, some researches also put forward different views, such as Ku Na Hyoen and Kweon Jihoon, who found that campus public streets are also spatial elements with high incidence of violence by investigating the surrounding environment of four schools with high rate of school violence (Kweon, 2016).

Secondly, the study also found that the spatial visibility of the SOE has an impact on the distribution of different types of violence, and is most significantly influenced by the plant communities and building outlines. The school peripheral spaces are greatly reduced in visibility and natural surveillance by the dense evergreen trees with large-sized canopies, making it the prime areas for physical conflict and extraneous invasive violence. And due to deciduous arbors, especially Camellia japonica L., Osmanthus fragrans, etc, the total and local visibility graphs of the SOE in winter significantly better than that in summer (Wang et al., 2022). In addition, there is no significant correlation between teacher-student conflict and spatial visibility, while less harmful verbal bullying occurs mainly in open spaces with moderate or good visibility. This conclusion is consistent with Wahab and Sakip, who, after conducting GIS analysis of the specific environment in which school violence occurs, concluded that building outlines, shrubs and decorative sculptures would obscure views and thus create places where school bullying is prevalent (Wahab & Sakip, 2020). However, this study believes that the plants that block the eyesight should not be removed directly (as an important element of the SOE, favourable landscaping can contribute to spatial amenity), but rather calls for the selection of plants with high trunks or small-sized canopies in addition to considering the ornamental nature when planning or renovating the campus design, so as to ensure the visibility of the surrounding environment (Sadjadi et al., 2021).

As a supplement, this study also classified the violence-prone spaces in the SOE of boarding school into four types, according to the performance of various violence occurrence spaces in terms of both spatial configurations and spatial visibility. In detail, it's carried out that, (1) the area with average or greater spatial configuration and visibility, and located within walkable layer is defined as violent hidden space, the place where verbal bullying with slight harm occurs frequently or no violence occurs, (2) the area located in the walkable layer with poor spatial configuration and visibility is defined as violent motivated space, which provoke the desire to commit violence and is the place where verbal bullying and physical conflict occur frequently, (3) violent detracted space refers to the area with average visibility but is located outside the walkable layer, often facilitating the perpetration of violence by potential perpetrators due to the poor territoriality and activity support, (4) the area outside the walkable layer with poor visibility is defined as the violent facilitated space, which is the place where extraneous invasive violence occurs frequently. The classification of violence occurrence spaces has been verified in the five types of crime places summarized by Paul Cozens and Terence Love (Cozens & Love, 2009; Scharpf et al., 2021).

Finally, it should be noted that there are still many limitations and deficiencies in this paper. And the most important thing is its failure to integrate the social intervention means into the spatial syntax simulation, and consider the influence of various elements such as color and texture in the SOE. Because relatively strict security management in spaces, such as the main roads and the school entrance, greatly reduces the probability of violence, while environmental colour can influence students' activities through vision. Furthermore, while CPTED and Spatial Syntax theory applied to the security research at city and block scales has developed more maturely, its application to schools, especially outdoor environment, is still very limited. This study evaluated the public security of the SOE in Case L by comprehensively using CPTED and Spatial Syntax theory, and the results showed consistency with the violence occurrence map, validating the feasibility of this method. But

in order to obtain more accurate and reasonable evaluation methods, we still need to carry out more researches thorough exploration with three-dimensional simulation software and evaluation system in the future.

Supplementary Tables

Supplementary table 1: Perpetrators, victims, bystanders, non-experiencers of different types of violence. N = 338, female 50.59%.

Violence types	Violence activities	Perpetrators (%)	Victims (%)	Bystanders (%)	Non-experiencers (%)
Teacher-student conflict	Cynicism	4.44 (15 stu.)	23.08 (78 stu.)	37.28 (126 stu.)	35.21 (119 stu.)
	Corporal punishment	6.21 (21 stu.)	21.01 (71 stu.)	38.17 (129 stu.)	34.62 (117 stu.)
Verbal bullying	Insulting nickname	15.98 (54 stu.)	13.02 (44 stu.)	41.42 (140 stu.)	29.59 (100 stu.)
	Isolating others	15.09 (51 stu.)	11.54 (39 stu.)	40.53 (137 stu.)	32.84 (111 stu.)
	Ridiculing others for the incompatibility of their personality with their gender	7.10 (24 stu.)	5.92 (20 stu.)	42.90 (145 stu.)	44.08 (149 stu.)
	Deliberately pushing others	7.99 (27 stu.)	4.44 (15 stu.)	44.08 (149 stu.)	43.49 (147 stu.)
	Verbal threat	9.47 (32 stu.)	9.47 (32 stu.)	43.49 (147 stu.)	37.57 (127 stu.)
	Refusing others to participate in collective activities	7.10 (24 stu.)	4.44 (15 stu.)	43.49 (147 stu.)	44.97 (152 stu.)
	Reject people of the same gender or opposite gender	8.58 (29 stu.)	5.92 (20 stu.)	42.01 (142 stu.)	43.49 (147 stu.)
Physical conflict	Kicking and beating others	17.75 (60 stu.)	8.58 (29 stu.)	33.73 (114 stu.)	39.94 (135 stu.)
	Fighting	6.67 (23 stu.)	5.33 (18 stu.)	52.89 (178 stu.)	35.21 (119 stu.)
Extraneous invasive violence	Intimidation and threat	1.48 (5 stu.)	9.17 (31 stu.)	39.94 (135 stu.)	46.15 (156 stu.)
	Blackmailing	3.25 (11 stu.)	5.33 (18 stu.)	39.94 (135 stu.)	51.48 (174 stu.)
	Affray	0.59 (2 stu.)	2.66 (9 stu.)	27.51 (93 stu.)	69.23 (234 stu.)

Supplementary table 2: Evaluation of tested students on the SOE. N = 338, female 50.59%.

Item	Strongly agreed (%)	Agreed (%)	Neutral (%)	Disagreed (%)	Strongly disagreed (%)
Visual blind spots in landscape space	7.99 (27 stu.)	11.24 (38 stu.)	52.07 (176 stu.)	13.31 (45 stu.)	15.38 (52 stu.)
Less road lamps or weak light	5.03 (17 stu.)	12.13 (41 stu.)	45.56 (154 stu.)	17.75 (60 stu.)	19.53 (66 stu.)
Remote dormitory building	6.80 (23 stu.)	11.54 (39 stu.)	45.27 (153 stu.)	16.86 (57 stu.)	19.53 (66 stu.)
Narrow school entrance and poor traffic order	13.02 (44 stu.)	15.98 (54 stu.)	43.49 (147 stu.)	13.31 (45 stu.)	14.20 (48 stu.)
Hidden space blind spots on campus	5.92 (20 stu.)	13.02 (44 stu.)	42.60 (144 stu.)	21.60 (73 stu.)	16.86 (57 stu.)
Lack of leisure facilities in public space	5.03 (17 stu.)	12.43 (42 stu.)	42.60 (144 stu.)	19.53 (66 stu.)	20.41 (69 stu.)
The stadium far away	8.58 (29 stu.)	11.54 (39 stu.)	42.01 (142 stu.)	17.16 (58 stu.)	17.75 (60 stu.)
No one manages campus greening landscape	0.89 (3 stu.)	5.33 (18 stu.)	41.72 (141 stu.)	21.30 (72 stu.)	30.77 (104 stu.)
Garbage not removed for a long period of time	1.48 (5 stu.)	5.03 (17 stu.)	38.46 (130 stu.)	22.49 (76 stu.)	32.54 (110 stu.)

No wall or too low walls in school	0.89 (3 stu.)	8.88 (30 stu.)	39.05 (132 stu.)	21.89 (74 stu.)	29.29 (99 stu.)
Lack of security patrols at night	4.73 (16 stu.)	10.65 (36 stu.)	42.90 (145 stu.)	21.30 (72 stu.)	20.41 (69 stu.)
Lack of security bulletin board	4.44 (15 stu.)	11.24 (38 stu.)	46.45 (157 stu.)	19.23 (65 stu.)	18.64 (63 stu.)
Lack of protective fence in dormitory	1.78 (6 stu.)	11.24 (38 stu.)	38.76 (131 stu.)	23.37 (79 stu.)	24.85 (84 stu.)
Too dense and chaotic road network	2.66 (9 stu.)	8.58 (29 stu.)	43.49 (147 stu.)	18.64 (63 stu.)	26.63 (90 stu.)
Confusing naming of school buildings	4.14 (14 stu.)	6.80 (23 stu.)	47.34 (160 stu.)	21.60 (73 stu.)	20.12 (68 stu.)
Public facilities damaged	1.78 (6 stu.)	9.76 (33 stu.)	45.86 (155 stu.)	18.64 (63 stu.)	23.96 (81 stu.)

Supplementary table 3: Values for the six parameters of the school outdoor space nodes.

Space node		**Int**	**MD**	**Conn**	**Cont**	**VCs**	**VCw**	**Violence Types**
1	Average	N/A	N/A	N/A	N/A	1,402.12	1,564.54	Extraneous invasive violence
	Minimum	N/A	N/A	N/A	N/A	451.00	1,348.00	
	Maximum	N/A	N/A	N/A	N/A	2,632.00	2,898.00	
2	Average	2.70	4.76	36.67	0.22	1,356.75	1,493.61	Teacher-student conflict, verbal bullying and physical conflict
	Minimum	2.14	4.54	11.00	0.17	861.00	1,293.00	
	Maximum	2.74	5.53	46.00	0.26	1,677.00	1,911.00	
3	Average	3.86	3.72	107.25	0.25	1,325.11	2,278.52	Verbal bullying and physical conflict
	Minimum	2.74	3.27	12.00	0.07	689.00	2,050.00	
	Maximum	4.27	4.54	202.00	0.33	1,771.00	2,805.00	
4	Average	N/A	N/A	N/A	N/A	1,200.09	1,703.31	Physical conflict
	Minimum	N/A	N/A	N/A	N/A	698.00	927.00	
	Maximum	N/A	N/A	N/A	N/A	2,823.00	3,003.00	
5	Average	N/A	N/A	N/A	N/A	1,597.15	1,642.77	Verbal bullying and physical conflict
	Minimum	N/A	N/A	N/A	N/A	737.00	966.00	
	Maximum	N/A	N/A	N/A	N/A	3,008.00	3,221.00	
6	Average	N/A	N/A	N/A	N/A	5,090.22	6,462.41	Physical conflict and extraneous invasive violence
	Minimum	N/A	N/A	N/A	N/A	1,437.00	2,011.00	
	Maximum	N/A	N/A	N/A	N/A	6,157.00	8,410.00	
7	Average	N/A	N/A	N/A	N/A	11,192.56	13,673.92	Physical conflict
	Minimum	N/A	N/A	N/A	N/A	5,588.00	6,489.00	
	Maximum	N/A	N/A	N/A	N/A	15,791.00	24,385.00	
8	Average	3.19	3.99	69.35	0.21	972.06	4,033.73	Teacher-student conflict, verbal bullying and physical conflict
	Minimum	2.70	3.61	43.00	0.15	628.00	3,462.00	
	Maximum	3.72	4.57	115.00	0.37	2,843.00	4,460.00	
9	Average	5.61	2.73	302.17	0.21	2,638.16	8,883.43	Teacher-student conflict and verbal bullying
	Minimum	4.79	2.09	87.00	0.06	735.00	1,505.00	
	Maximum	8.84	3.03	342.00	0.43	6,220.00	15,313.00	
10	Average	5.24	2.98	245.71	0.08	5,976.23	7,980.15	Verbal bullying
	Minimum	4.28	2.41	76.00	0.05	5,664.00	7,391.00	
	Maximum	8.11	3.26	749.00	0.33	6,257.00	8,741.00	
11	Average	8.32	2.25	1,078.76	0.29	22,078.06	24,714.76	Verbal bullying

	Minimum	6.62	2.06	323.00	0.10	9,984.00	4,889.00	
	Maximum	9.13	2.58	1,613.00	0.40	30,201.00	35,310.00	
12	Average	N/A	N/A	N/A	N/A	2,235.52	8,230.61	Physical conflict and
	Minimum	N/A	N/A	N/A	N/A	258.00	698.00	extraneous invasive
	Maximum	N/A	N/A	N/A	N/A	4,263.00	23,439.00	violence
13	Average	N/A	N/A	N/A	N/A	2,529.23	27,794.47	Physical conflict and
	Minimum	N/A	N/A	N/A	N/A	195.00	13,061.00	extraneous invasive
	Maximum	N/A	N/A	N/A	N/A	5,529.00	34,007.00	violence
14	Average	4.59	3.13	181.54	0.21	20,658.16	23,841.45	Teacher-student
	Minimum	3.14	2.70	68.00	0.17	7,648.00	10,951.00	conflict and verbal
	Maximum	4.61	4.08	223.00	0.24	28,701.00	33,048.00	bullying
15	Average	3.82	3.61	167.21	0.38	10,540.24	14,275.05	Teacher-student
	Minimum	3.15	3.10	132.00	0.22	3,696.00	3,928.00	conflict and verbal
	Maximum	4.61	4.06	221.00	0.68	16,014.0	22,157.00	bullying
16	Average	N/A	N/A	N/A	N/A	2,037.18	3,421.03	Physical conflict
	Minimum	N/A	N/A	N/A	N/A	343.00	1,682.00	
	Maximum	N/A	N/A	N/A	N/A	4,615.00	6,071.00	
17	Average	N/A	N/A	N/A	N/A	1,996.64	2,851.46	Physical conflict and
	Minimum	N/A	N/A	N/A	N/A	480.00	997.00	extraneous invasive
	Maximum	N/A	N/A	N/A	N/A	4,786.00	5,669.00	violence
18	Average	4.46	3.01	109.47	0.11	4,845.33	4,911.28	Verbal bullying
	Minimum	3.76	2.65	42.00	0.06	2,458.00	4,810.00	
	Maximum	5.88	3.58	203.00	0.18	6,721.00	7,065.00	
19	Average	N/A	N/A	N/A	N/A	666.67	2,197.07	Physical conflict and
	Minimum	N/A	N/A	N/A	N/A	179.00	270.00	extraneous invasive
	Maximum	N/A	N/A	N/A	N/A	1,487.00	6,228.00	violence
20	Average	2.48	5.02	99.29	0.38	782.41	1,252.35	Physical conflict and
	Minimum	2.21	4.42	74.00	0.24	126.00	308.00	extraneous invasive
	Maximum	2.81	5.39	147.00	0.51	1,736.00	1,903.00	violence

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Reference

UNESCO. (2017). *School Violence and Bullying: Global Status Report*, Paris: UNESCO, pp. 9.

Riehm, K. E., Mojtabai R., Adams L. B., et al. (2021). Adolescents' Concerns About School Violence or Shootings and Association With Depressive, Anxiety, and Panic Symptoms, *JAMA Netw Open*, 4(11), e2132131. doi: https://doi.org/10.1001/jamanetworkopen.2021.32131

Ferrara, P., Franceschini, G., Villani, A. et al. (2019). Physical, psychological and social impact of school violence on children, *Italian Journal of Pediatrics*, 45, e76. doi: https://doi.org/10.1186/s13052-019-0669-z

UNESCO. (2018). *School Violence and Bullying: Global Status and Trends, Drivers and Consequences*, Paris: UNESCO, pp. 4-7.

Ministry of Education, PRC. (2018). National Statistical Bulletin on the Development of Education in 2017. [Online]. Available: http://www.moe.gov.cn/jyb_sjzl/sjzl_fztjgb/201807/t20180719_343508.html

Wang, W. D. (2016). How much school bullying shouldn't happen? [Online]. Available: https://epaper.gmw.cn/gmrb/html/2016-12/15/nw.D110000gmrb_20161215_1-15.htm

Zeng, M. L., Sun, W. Y., Mao, Y. Y., et al. (2018). Study and enlightenment on prevention measures of overseas campus crime, *Urban Design*, 5, pp. 64-73. doi: https://doi.org/10.16513/j.urbandesign.2018.05.008 (in Chinese)

Burger, C. A., Strohmeier, D., Spröber, N., et al. (2015). How teachers respond to school bullying: An examination of self-reported intervention strategy use, moderator effects, and concurrent use of multiple strategies, *Teaching and Teacher Education*, 51, pp. 191-202. doi: https://doi.org/10.1016/j.tate.2015.07.004

Foody, M., Challenor, L., Murphyy, H., et al. (2018). The Anti-Bullying Procedures for Primary and Post-Primary Schools in Ireland: What Has Been Achieved and What Needs to be Done, *Bildung und Erziehung*, 71, pp. 88-97. doi: https://doi.org/10.13109/buer.2018.71.1.88

Kalichman, S. C. and Brosig, C. L. (1992). Mandatory Child Abuse Reporting Laws: Issues and Implications for Policy, *Law & Policy*, 14, pp. 153-168. doi: https://doi.org/10.1111/j.1467-9930.1992.tb00080.x

Kim, M. (2015). *The Police Action Against School Violence in Korea*, master's thesis, Beijing, China: Tsinghua University.

Cowie, H. (2011). Peer Support as an Intervention to Counteract School Bullying: Listen to the Children, *Children & Society*, 25, 287-292. doi: https://doi.org/10.1111/j.1099-0860.2011.00375.x.t

Sairanen, L. and Pfeffer, K. (2011). Self-reported handling of bullying among junior high school teachers in Finland, *School Psychology International*, 32, pp. 330-344. doi: https://doi.org/10.1177/0143034311401795

Bradshaw, C. P., Waasdorp, T. E., Debnam, K. J., et al. (2014). Measuring school climate in high schools: a focus on safety, engagement, and the environment, *Journal of school health*, 84, pp. 593-604. doi: https://doi.org/10.1111/josh.12186

Kim, D. W. and Jung, S. W. (2018). Analysis of Trends in Research Published in the 'Journal of Community Safety and Security by Environmental Design' Using the Semantic Network Analysis Method, *Journal of Community Safety and Security by Environmental Design*, 9(2), pp. 9-31. doi: https://doi.org/10.26470/JCSSED.2018.9.2.9

Atlas, R. (2013). *21st Century Security and CPTED: Designing for Critical Infrastructure Protection and Crime Prevention*, 2nd ed. Boca Raton: CRC Press.

Frank, R., Andresen, M. A. and Brantingham, P. L. (2011). Criminal directionality and the structure of urban form, *Journal of Environmental Psychology*, 32, pp. 37-42. doi: https://doi.org/10.1016/j.jenvp.2011.09.004

Cozens, P. M., Saville, G. and Hillier, D. (2005). Crime prevention through environmental design (CPTED): a review and modern bibliography, *Property Management*, 23(5), pp. 328-356. doi: https://doi.org/10.1108/02637470510631483

Armitage, R. (2018). Burglars' take on crime prevention through environmental design (CPTED): reconsidering the relevance from an offender perspective, *Security Journal*, 31, pp. 285-304. doi: https://doi.org/10.1057/s41284-017-0101-6

Jacobs, J. (1961). *The Death and Life of Great American Cities*, New York: Vintage Books.

Jeffery, C. R. (1971). *Crime Prevention Through Environmental Design*, Beverly Hills, CA: Sage Publications.

Newman, O. (1972). *Defensible Space: Crime Prevention through Urban Design*, New York: Macmillan.

Cozens, P. and Love, T. (2015). A Review and Current Status of Crime Prevention through Environmental Design (CPTED), *Journal of Planning Literature*, 30, pp. 393-412. doi: https://doi.org/10.1177/0885412215595440

Airaksinen, J., Aaltonen, M., Tarkiainen, L., et al. (2021). Associations of neighborhood disadvantage and offender concentration with criminal behavior: Between-within analysis in Finnish registry data, *Journal of Criminal Justice*, 74, e101813. doi: https://doi.org/10.1016/j.jcrimjus.2021.101813

Alsharif, M. A., Peters, M. D. and Dixon, T. J. (2020). Designing and Implementing Effective Campus Sustainability in Saudi Arabian Universities: An Assessment of Drivers and Barriers in a Rational Choice Theoretical Context, *Sustainability*, 12, e5096. doi: https://doi.org/10.3390/su12125096

Bernasco, W. (2007). The usefulness of measuring spatial opportunity structures for tracking down offenders: A theoretical analysis of geographic offender profiling using simulation studies, Psychology, *Crime & Law*, 13, pp. 155-171. doi: https://doi.org/10.1080/10683160600558402

Piroozfar, P., Farr, E. R. P., Aboagye-Nimo, E., et al. (2019). Crime prevention in urban spaces through environmental design: A critical UK perspective, *Cities*, 95, e102411. doi: https://doi.org/10.1016/j.cities.2019.102411

Mihinjac, M. and Saville, G. (2019). Third-Generation Crime Prevention Through Environmental Design (CPTED), *Social Sciences*, 8, e182. doi: https://doi.org/10.3390/socsci8060182

Wahab, A. A., Sakip, S. R. and Zainol, H. (2018). An Assessment of CPTED Principles in Relation to Bullying Behaviour, *Advances in Applied Sociology*, 8, pp. 25-48. doi: https://doi.org/10.4236/aasoci.2018.81002

Gibson, V. and Johnson, D. (2016). CPTED, but not as we know it: Investigating the conflict of frameworks and terminology in crime prevention through environmental design, *Security Journal*, 29, pp. 256-275. doi: https://doi.org/10.1057/sj.2013.19

Crowe, T. D. (2000). *Crime Prevention Through Environmental Design: Applications of Architectural Design and Space Management Concepts*, 2nd ed. Boston, MA: Butterworth-Heinemann.

Lamoreaux, D. J. and Sulkowski, M. L. (2020). Crime Prevention through Environmental Design in schools: Students' perceptions of safety and psychological comfort, *Psychology in the Schools*, 58, pp. 475-493. doi: https://doi.org/10.1002/pits.22459

Arabi, M., Naseri, T. S. and Jahdi, R. (2020). Use All Generation of Crime Prevention through Environmental Design (CPTED) for Design urban Historical Fabric (Case Study:

The central area of Tehran Metropolis, Eastern Oudlajan), *Ain Shams Engineering Journal*, 11, pp. 519-533. doi: https://doi.org/10.1016/j.asej.2019.11.003

Liu, C. (2014). Environment Redesigned for Crime Prevention with CPTED Strategies — A Case Study of Typical Chinese Community, *Applied Mechanics and Materials*, 584–586, pp. 805–810. doi: https://doi.org/10.4028/www.scientific.net/amm.584-586.805

Rupp, L. A., Zimmerman, M. A., Sly, K. W., et al. (2020). Community-Engaged Neighborhood Revitalization and Empowerment: Busy Streets Theory in Action, *American journal of community psychology*, 65, pp. 90-106. doi: https://doi.org/10.1002/ajcp.12358

Surette, R. and Stephenson, M. (2019). Expectations versus effects regarding police surveillance cameras in a municipal park, *Crime Prevention and Community Safety*, 21, pp. 22-41. doi: https://doi.org/10.1057/s41300-018-0058-3

Mingyun, C., Park, C. and Jang J. (2018). The Effects of Urban Park and Vegetation on Crime in Seoul and Its Planning Implication to CPTED, *Journal of the Korean Institute of Landscape Architecture*, 46, pp. 27-35. doi: https://doi.org/10.9715/kila.2018.46.3.027

Hong, Y. S. (2017). A Case Study on Application of CPTED of Park Development Guidelines: With Suwon-City Park Development Guidelines as a Case, *Journal of Environmental Science International*, 26, pp. 97-107. doi: https://doi.org/10.5322/JESI.2017.26.1.97

Sun, Y. N. (2017). *The Research on the Design Method of Crime Prevention in Hospital Buildings*, master's thesis, Beijing, China: Beijing University of Civil Engineering and Architecture.

Peiser, R. and Chang, A. (1998). *Situational crime prevention in Cerritos and paramount industrial parks. In: Felson MP, ed. Reducing Crime Through Real Estate Development and Management*, Washington, DC: Urban Land Institute, pp. 91-101.

Jones, F. and Sloboden, J. (2017). Jacksonville, Florida, Transportation Authority's Mobility Corridors: Improving Transit System Performance Through Enhanced Safety and Urban Design, *Transportation Research Record*, 2651, pp. 118-126. doi: https://doi.org/10.3141/2651-13

Takizawa, A., Koo, W. and Katoh, N. (2010). Discovering Distinctive Spatial Patterns of Snatch Theft in Kyoto City with CAEP, *Journal of Asian Architecture and Building Engineering*, 9, pp. 103-110. doi: https://doi.org/10.3130/jaabe.9.103

Aziz, N. A. A. (2020). Space Syntax as a Tool to Measure Safety in Small Urban Parks—a Case Study of Rod El Farag Park in Cairo, Egypt, *Landscape Architecture Frontiers*, 8, pp. 42-59. doi: https://doi.org/10.15302/J-LAF-1-020034

Matijosaitiene, I. (2016). Combination of CPTED and space syntax for the analysis of crime, *Safer Communities*, 15(1), pp. 49-62. doi: https://doi.org/10.1108/SC-05-2015-0013

Hillier, B. and Hanson, J. (1984). *The Social Logic of Space*, Cambridge: Cambridge University Press.

Ostwald M. J. (2011). The Mathematics of Spatial Configuration: Revisiting, Revising and Critiquing Justified Plan Graph Theory, *Nexus network journal: Architecture and mathematics*, 13, pp. 445-470. doi: https://doi.org/10.1007/s00004-011-0075-3

Vagi, K. J., Stevens, M. R., Simon, T. R., et al. (2018). Crime Prevention Through Environmental Design (CPTED) Characteristics Associated With Violence and Safety in Middle Schools, *Journal of school health*, 88, pp. 296-305. doi: https://doi.org/10.1111/josh.12609

Nettle, D., Nott, K. and Bateson, M. (2012). Cycle thieves, we are watching you: impact of a simple signage intervention against bicycle theft, *PloS one*, 7, e51738. doi: https://doi.org/10.1371/journal.pone.0051738

Shariati, A. and Guerette, R. T. (2019). Resident Students' Perception of Safety in On-Campus Residential Facilities: Does Crime Prevention through Environmental Design (CPTED) Make a Difference, *Journal of School Violence*, 18, pp. 570-584. doi: https://doi.org/0.1080/15388220.2019.1617721

Lin, D. Y. (2018). *An Empirical Study on the Countermeasure and the Influential Factor of Bullying Victimization in Junior Middle School-Based on CEPS' Data (2016) in Jiangsu, Zhejang and Shanghai*, master's thesis, Hangzhou, China: Zhejiang University.

Kim, D., Hong, S. W. and Jeong, Y. (2019). Crime Prevention Effect of the Second Generation Crime Prevention through Environmental Design Project in South Korea: An Analysis, *Social Sciences*, 8, e187. doi: https://doi.org/10.3390/socsci8060187

Ministry of Education, PRC. (2012). National Statistical Bulletin on the Development of Education in 2011. [Online]. Available: http://www.moe.gov.cn/srcsite/A03/s180/moe_633/201208/t20120830_141305.html

Li, H. M. (2018). *A Study on the Strategy of Prevention and Control of Bullying in the Rural Boarding Schools: Case of S Township Middle School in Henan Province*, master's thesis, Chongqing, China: Southwest University.

Summers, L. and Johnson, S. D. (2017). Does the configuration of the street network influence where outdoor serious violence takes place? Using space syntax to test crime pattern theory, *Journal of Quantitative Criminology*, 33(2), pp. 397–420. doi: https://doi.org/10.1007/s10940-016-9306-9

Hillier, B. (1996). *Space is the Machine: A Configurationally Theory of Architecture*, Cambridge: Cambridge University Press.

Tomita M., Tago T. and Ohuchi H. (2003). Correlation between Color Composition of District, Environment Recognition and Behavioral Characteristics in Cityscape: Case study in Ginza and Harajuku area (Environmental Engineering), *AIJ Journal of Technology and Design*, 9, pp. 279-282. doi: https://doi.org/10.3130/aijt.9.279 (in Japanese)

Braun, C. C., Greeno, B. and Silver, N. C. (1994). Differences in Behavioral Compliance as a Function of Warning Color, *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, 38(5), pp. 379-383. doi: https://doi.org/10.1177/154193129403800506

Curtis, J. W. (2012). Integrating Sketch Maps with GIS to Explore Fear of Crime in the Urban Environment: A Review of the Past and Prospects for the Future, *Cartography and Geographic Information Science*, 39, pp. 175-186. doi: https://doi.org/10.1559/15230406394175

Zhao Q. (2013). *On Application of Space Syntax in Research of Spatial Structure of the Residential park: Hefei as Example*, master's thesis, Hefei, China: Anhui Jianzhu University.

Steventon, G. (1996). Defensible space: A critical review of the theory and practice of a crime prevention strategy, *Urban Design International*, 1(3), pp. 235-245. doi: https://doi.org/10.1080/135753196351010

Xu L. Q. (2002). Community Security and Environment Design: Behind the Defensible Space. *Journal of Tongji University (Social Science Section)*, 13, pp. 34-39. (in Chinese)

Changhun L. (2017). School Territories and Complementary Strategies of CPTED for Each School Territory, *Journal of Community Safety and Security by Environmental Design*, 8, pp. 179-216. doi: https://doi.org/110.26470/JCSSED.2017.8.2.179

Wang S. S. (2017). *The Research on Design Strategy of the Kindergarten Front District Attached to College and Scientific Institute in Wushan Guangzhou*, master's thesis, Guangzhou, China: South China University of Technology.

Kweon, J. (2016). A Study on Quantitative CPTED Guideline Selection Model for Public Street Considering Spatial Characteristics of Juvenile Crimes in School Surroundings, *Journal of Digital Design*, 16, pp. 1-10.

Wang, H., Tang, J., Dill, S. E. et al. (2022). Bullying Victims in Rural Primary Schools: Prevalence, Correlates, and Consequences, *International Journal of Environmental Research and Public Health*, 19, e765. doi: https://doi.org/10.3390/ijerph19020765

Wahab, A. A. and Sakip, S. R. M. (2020). Mapping Isolated Places in School in Concurrence with Bullying Possibility Elements, *Environment-behavior Proceedings Journal*, 4, pp. 359-366. doi: https://doi.org/10.21834/e-bpj.v4i12.1913

Cozens, P. and Love, T. (2009). Manipulating Permeability as a Process for Controlling Crime: Balancing Security and Sustainability in Local Contexts, *Built Environment Journal: Special Issue on Security Versus Safety: How to Deliver Less Crime and More Sustainable Design*, 35, pp. 346-365. doi: https://doi.org/10.2148/benv.35.3.346

Scharpf, F., Kirika, A., Masath, F. B., et al. (2021). Reducing physical and emotional violence by teachers using the intervention Interaction Competencies with Children—For Teachers (ICC-T): Study protocol of a multi-country cluster randomized controlled trial in Ghana, Tanzania, and Uganda, *BMC Public Health*, 21, e1930. doi: https://doi.org/10.1186/s12889-021-11950-y

Sadjadi, M., Blanchard, L., Brülle, R., et al. (2021). Barriers and facilitators to the implementation of Health-Promoting School programmes targeting bullying and violence: A systematic review, *Health Education Research*, 36, pp. 581-599. doi: https://doi.org/10.1093/her/cyab029