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Assessment of Perceived Factors of Road Safety in Rural Left-Behind Children's Independent Travel: A Case Study in Changsha, China

Yue Tang [1], Li Zhu [1,*], Jiang Li [1], Ni Zhang [1], Yilin Sun [2], Xiaokang Wang [2] and Honglin Wu [1]

1 School of Architecture and Art, Central South University, Changsha 410083, China; 211301005@csu.edu.cn (Y.T.); lijiang@csu.edu.cn (J.L.); nizhang25@163.com (N.Z.); 221311060@csu.edu.cn (H.W.)
2 Research Center of Chinese Village Culture, Central South University, Changsha 410083, China; 210501002@csu.edu.cn (Y.S.); 220501002@csu.edu.cn (X.W.)
* Correspondence: 207131@csu.edu.cn; Tel.: +86-13973188406

Abstract: The disparity between urban and rural development in China has resulted in the significant migration of rural laborers to urban areas, giving rise to a growing population of left-behind children in rural areas. The number of accidental injuries among these children traveling independently is increasing, suggesting that road safety in rural areas should be of concern. This study explored factors affecting road safety for left-behind rural children traveling independently. The data were collected from a survey conducted in four villages in Changsha, China. The study used a variety of methods, including spatial syntax, linear regression analysis, Pearson correlation analysis, and stepwise regression analysis, to analyze factors affecting road safety for rural left-behind children traveling independently. The study revealed significant differences in road safety perceptions among rural left-behind children and their guardians. Road safety perceptions were significantly higher for left-behind children. Factors such as plant density, turning angle, road scale, road slope, recognizable signs, internal corner space, animal danger, enclosure type, electronic tools, monitoring facilities, strangers, and social concerns were found to be significantly related to road safety perceptions of left-behind children traveling independently. The findings suggested that left-behind children who travel independently in rural areas face a potential risk of accidental injuries. These results can be used by decision makers to improve the rural road environment and to provide useful assistance for the healthy growth of left-behind children.

Keywords: left-behind children; traveling independently; children's health; rural roads; safety perception

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1. Introduction

Extensive Chinese literature argues that many people from rural populations have been moving into urban areas to seek employment opportunities, which has resulted in a sharp increase in left-behind children in China [1,2]. In 2016, the Chinese government clarified that a left-behind child is a child under the age of 16 who cannot live with both parents because one or both parents are working outside the country for at least three months [3]. These children live in rural areas; travel or attend school alone [4–6]; and are cared for by grandparents, relatives, or siblings, or by themselves. Their parents rarely return home, and even when they do visit their children, they only stay for very short periods of time [7,8].

Thousands of children are considered to be left behind in low- and middle-income countries. For example, it has been estimated that 27% of children in the Philippines, 36% of children in Ecuador, and 40% of children in rural South Africa have at least one migrant parent [9]. Statistics on left-behind children in rural China showed that there were 6.97 million left-behind children in rural China in 2018. Of these, 21.7% were aged

0–5 years; 67.4% were aged 6–13 years; and 10.9% were aged 14–16 years. Of these left-behind children, 54.5% were male and 45.5% were female. In total, 96% of left-behind children in rural areas are cared for by grandparents, and 4% are cared for by relatives and friends [10]. In 2021, the number of left-behind children aged 6–16 reached 11.92 million, including 7.779 million in primary schools and 4.212 million in secondary schools [11]. These studies show that the number of left-behind children in rural China has remained on an upward trend over the last five years.

The risk of accidental injury in the travel environment is an important issue for left-behind children in rural China. Research findings have shown 252.9 self-inflicted injuries per 1000 cases of left-behind children, compared with 119.8 for children living with both biological parents [12,13]. These injuries include car crashes, falls, drownings, and animal bites [14], most of which occur on highways/streets/roads during independent travel [15]. This is because the infrastructure construction in some rural areas is not as sound and safe as that in cities [16]. The large number of left-behind children in rural areas who lack proper attention [17–19] and are exposed to dangerous environments has serious consequences [20,21]. Left-behind children remain highly physically vulnerable [22,23]. Therefore, research on the safety of road environments for independent travel by left-behind children in rural areas could help to reduce risk factors in the environment and to improve the safety of left-behind children.

Independent travel by rural left-behind children reflects the extent to which a child is willing to travel to nearby destinations, walk around the neighborhood, cross major roads, and ride transit without adult companionship [24]. Some research revealed that for Pacific parents in New Zealand, 'people danger' was the most common reason for not letting their children go out alone, while for Asian and Indian parents, 'traffic danger' was the most common reason for concern [25]. The safety of the independent travel environments for rural left-behind children is mainly related to the physical and social environment in rural areas [26]. Road traffic safety [27] and travel distance [28] are important physical environmental factors. It was found that the main impact factors on road traffic safety for the independent travel of children were effective walking width, spatial connectivity, visual integration, pedestrian safety obstruction, completeness of crossing facilities, and impact of traffic flow [29]. Travel distance for the majority of children aged 6–12 was found to be limited to short distances (a five-minute walk) and few destinations (e.g., a friend's/relative's home) [30]. Children's fear of strangers [31], parental support [32], bullying [33], and animal danger [14] are important social environmental factors in neighborhood environmental quality [34]. It may be that a strong perception of neighborhood social cohesion mitigates concerns about neighborhood safety (stranger danger, crime, and bullying) and thereby increases the willingness of children to enjoy greater independent mobility [35,36].

However, most related studies have focused on social environmental factors and have typically focused only on the perceptions of neighborhood environmental attributes of parents of urban children [37]. Few studies have systematically analyzed rural travel environments, particularly the independent travel paths of left-behind children. In China's rural society, the proportion of left-behind children is on the rise in rural areas, where environmental facilities lag significantly behind those in urban areas. Potential environmental accidents can affect the safety of left-behind children traveling alone.

In summary, in view of the different findings in this area, our study focused on the following research questions:

1. Which factors affect the safety of rural left-behind children traveling alone?
2. Are there differences in safety perceptions among rural left-behind children of different ages and genders?
3. Do rural left-behind children and their guardians have different perceptions of safety?

The remainder of the paper is organized as follows: Section 2 is devoted to the research methodology, research areas, data sources, and indexing system. In Section 2.1, the use of methods such as interviews with guardians and children, spatial syntax, information weighting method, and Pearson statistics are introduced as analysis methods in this study.

Section 2.2 presents the basics of the specific research scope of this study. Section 2.3 explains the sources of data acquisition in this study such as questionnaire data and road data. Section 2.4 explains the index system that affects road safety perceptions of left-behind children. Section 3 is devoted to the evaluation results regarding roads, guardians, and left-behind children of different genders and ages in the study area. In this section, Section 3.1 explains the potential traffic rate of left-behind children traveling alone on the road, and Section 3.2 explains and analyzes the results of the analysis of Pearson, linear regression, information weighting, and other methods through reliability and validity tests of repeated distributed questionnaires. In addtion, we present the results of an analysis of the safety perceptions of left-behind children and their guardians, with male and female left-behind children aged 6–12 and 13–16, on travel roads in the study region. Section 4 combines the analytical results of Section 3 with the conclusions in the related literature for a multi-level discussion. Section 5 summarizes the ideas and results of the whole paper.

2. Materials and Methods

2.1. Study Methods

This study focused on the road safety of independent travel for left-behind children in Guangming Village, Wangcheng District, Changsha City, China, and the surrounding countryside.

First, characteristics and patterns of the independent travel behavior of children were observed and recorded through fieldwork and interviews. Space syntax analysis was used to study roads with a high frequency of left-behind children in the region, and information weight statistics and linear regression analysis were performed.

Second, two offline and online questionnaires were conducted with left-behind children and their caregivers in the study area, and the Likert scale [38] was used to obtain their subjective assessment of the road safety elements. With the evaluation of road environment factors as the independent variable and the safety of road environment considered by left-behind children and their guardians as the dependent variable, Pearson correlation analysis and stepwise regression analysis were carried out to identify the correlation factors affecting the independent road safety of left-behind children in the study area, and the weight of the correlation factors was calculated using the entropy weight method.

Finally, the standard deviations and means of the relevant factors affecting the independent road safety perceptions of left-behind children and their guardians of different ages and genders were collected to analyze the differences in the safety perceptions of the groups of children.

2.2. Study Samples

The research area was located in Guangming Village, northwest of Bairuopu Town, Wangcheng District, Changsha. Jinzhou Avenue runs through the village, connecting Changsha and Ningxiang cities. The village borders Ningxiang City on the west, Jinzhi Village and Datang Village on the north and east, and Huangnipu Village on the south, as shown in Figure 1. There are 42 groups of villagers in Guangming Village, with 973 households and a total population of 3723. The total land area is 8 square kilometers and consists of 3484 mu of arable land, 1397 mu of dry soil, and 5886 mu of woodland. Most of the village's children between the ages of 6 and 12 attend Guangming Village Primary School, which has 281 students. Most of the children aged between 13 and 16 attend You Ren Secondary School. Most children travel independently to and from school Monday through Friday.

2.3. Data Source

This study obtained relevant data of the study area through field surveys, on-site interviews, questionnaires, cartography, and a public data open platform.

As Changsha has a typical subtropical monsoon climate, January is the coldest month in winter, with an average monthly temperature of 4.4 °C to 5.1 °C. The average daily temperature in summer is above 30 °C. This is not conducive for children to go out for independent activities. Hence, the observations were scheduled for April and May, when the weather was favorable for the children's independent activities. The team organized six researchers with professional backgrounds to observe and record the independent travel patterns of left-behind children in the study area from 6:30 to 11:30, 12:30 to 14:30, and 15:30 to 19:00. Most of our surveys were conducted at school gates, on the way home from school, etc.

Figure 1. Study regional location analysis. The white dashed line shows the extent of the different villages in the study area.

First, we sampled the field photos and videos of roads, and a total of 482 field photos of road environments were collected. The road opening data for the study area were obtained through Map World: Hunan Provincial Common Geospatial Information Service Platform [39].

Second, the data acquisition of the questionnaire was divided into two phases. The first phase, scheduled for April 2023, focused on left-behind children aged 6–16 and their guardians in the study area. The offline questionnaire was delivered as a face-to-face interview. The second phase was to adopt the questionnaire star platform in May 2023, mainly targeting guardians of left-behind children in the study region. For children who were unable to understand the questionnaire questions, it was completed by their caregiver.

Finally, we conducted two different questionnaires. A total of 328 responses to questionnaires were obtained. The final sample size for the study was 300, after screening for 28 invalid questionnaires. There were 100 online questionnaires and 200 offline questionnaires, as shown in Figure 2.

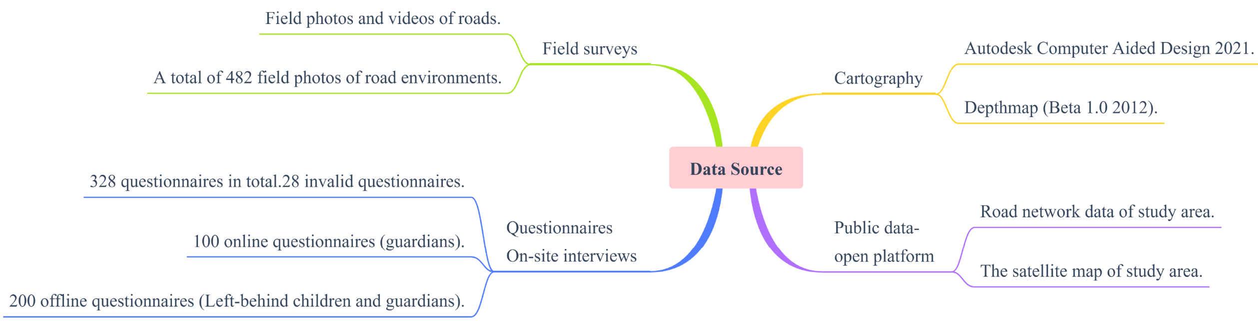


Figure 2. The flow chart of data sources.

2.4. Index System Construction

On the basis of reviewing the existing research literature, combining the rationality of relevant literature, evaluation tools, and relevant indicators [40,41], the difficulty of data collection, as well as the actual needs and behavioral characteristics of children's independent travel, this paper summarizes the environmental safety factors related to the roads used for the independent travel of rural left-behind children. Factors affecting the frequency of independent travel for children at four levels were initially screened. Second, the current situation of road space for the independent travel of left-behind children in the study area was analyzed through field studies, missing factors were added, and 20 influencing factors were finally identified as study variables, as shown in Table 1.

Table 1. Road safety indicators for independent travel for children left behind in rural areas.

Category	Variable	Interpretation
Vision Permeability	Plant density	Plants shade the road and create visual blind spots.
	Recognizable signs	Danger zone warning signs alert children to the dangers of the current environment.
	Turning angle	The size of the angle affects road visibility.
	Lighting system	The sufficiency of the illumination at night.
Interface Dissociability	Boundary staggered layer	The ratio of the width of the road to the adjacent boundary.
	Enclosure type	One-sided, two-sided, and three-sided enclosing patterns of roads.
	Guardrail ratio	Installed guardrails in dangerous areas such as water bodies and steep slopes.
	Internal corner space	The courtyard space between the building and the road.
Travel Accessibility	Road scale	Road width and whether people and vehicles are separated.
	Road slope	The angle between the lowest and highest point of a road.
	Hard pavement	Roads are paved with cement, asphalt, and other hard materials.
	Potential path	The closest and most frequented travel route.
Neighborhood Shelter	Dangerous animals	Being attacked by stray dogs, geese, and other animals.
	Strangers	Strangers are frequent on the roads.
	Street eye	Window-fronted residential buildings face the road.
	Abandoned space	Dilapidated buildings, construction sites, etc., where accidents can occur.
	Electronic tools	Wearing smart watches, mobile phones, and other communication tools.
	Acquaintances present	The road is beside a place where acquaintances often hang out.
	Social concerns	Bullies are frequent on the road.
	Monitoring facilities	Roads with real-time video surveillance.

3. Results

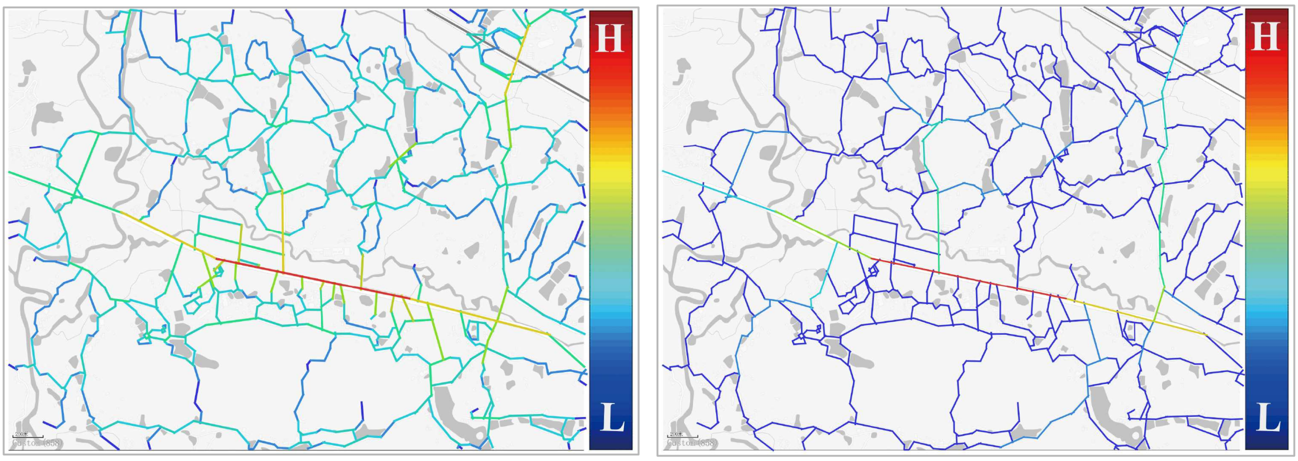
3.1. High-Frequency Selective Analysis of Independent Travel Road Scenes of Left-Behind Children

Based on spatial syntax, linear regression analysis, and the information weighting method, we calculated the potential travel frequency of independent roads for left-behind children in the study area.

First, based on spatial syntactic analysis, the location integration and choice degrees of roads in the studied region were obtained. The road data of the study area were fed into Auto CAD (Autodesk Computer Aided Design 2021) to build an axial model of the study area [42,43], as shown in Figure 3, which was then imported into Depthmap (Beta 1.0 2012) for quantitative analysis to compute the degree of location integration [44] and the choice [45] of roads in the study area. The warmer the axis color (tends to be red), the higher the location integration degree and choice degree. Cooler axis colors (favoring blue) represented lower location integration and choice, as shown in Figure 4. The higher the degree of location integration (n = 3), the greater the possibility of children's travel choice within 1000 m of the road. The higher the degree of choice, the more likely the road was to be crossed by traffic and people.

(**a**) (**b**)

Figure 3. The construction of the axis model of the research area. (**a**) Data on regional road distribution; (**b**) the road axis model of the study area.



(**a**) (**b**)

Figure 4. Road location integration and choice analysis in the study area. (**a**) Location integration of road; (**b**) choice of road.

The equation of integration:

$$RA_i = \frac{2(MD_i - 1)}{n - 2} \tag{1}$$

RA_i is the integration-value variable. n is the topological meaning of the number of all the nodes in the connected graph, and MD_i is the topological meaning of the mean depth [46].

The equation of choice:

$$c_x = \sum_{j=1}^{k} \frac{1}{L_j} \tag{2}$$

where k is the number of axes directly connected to x; j is the axes directly connected to x; j is an integer, $1 \leq j \leq k$; and L_j is the connection value of the j axes [47].

Secondly, based on linear regression analysis, the correlation between location integration and choice was determined. Since the number of axis models was 785, more than 100, 40 axes (top 5%) with the highest scores in location integration and choice were selected for linear regression analysis and weight calculation of information volume, with the location integration as the independent variable and choice as the dependent variable [48]. The formula of the model was as follows: choice = 1.472 + 0.000 * location integration. The R-square value of the model was 0.965, which meant that location integration can explain 96.5% of the change in choice. Through the F test (F = 1038.704, $p = 0.000 < 0.05$), the regression coefficient value of location integration was 0.000 (t = 32.229, $p = 0.000 < 0.01$). This meant that location integration had a significant positive influence on choice, as shown in Table 2.

Table 2. Results of linear regression analysis. (n = 40).

	Nonstandardized Coefficient		Standardization Coefficient	*t*	*p*	VIF
	B	Standard Deviation	Beta			
Constant	1.472	0.017	-	84.193	0.000 **	-
Location integration	0.000	0.000	0.982	32.229	0.000 **	1.000
R^2			0.965			
Adjust R^2			0.964			
F			*F* (1,38) = 1038.704, *p* = 0.000			
D-W value			0.773			

Dependent variable: choice. ** $p < 0.01$.

Finally, the weight of location integration was 0.7998 and the weight of choice was 0.2002 by means of the information weight method, as shown in Table 3. According to the weight value, the location integration and choice of 40 axes were supernaturally calculated, and the 16 roads with the highest passing frequency for left-behind children in the study area were obtained, as shown in Figure 5. In addition, the perspective of child walkers with a height of 1.2 m was taken for travel to the study area. Field images of the most frequented roads were obtained every 200 m, as shown in Figure 6.

Table 3. Results of the weight information method.

Item	Average Value	Standard Deviation	CV Coefficient	Weight
Location integration	111,328.025	69,465.157	62.40%	0.7998
Choice	1.952	0.305	15.62%	0.2002

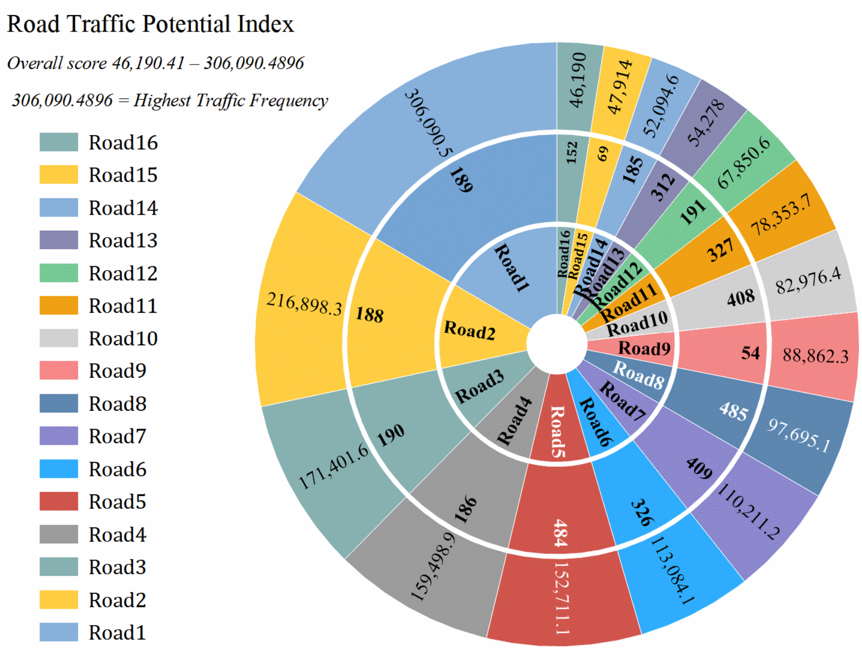


Figure 5. The potential traffic frequency calculation of regional roads.

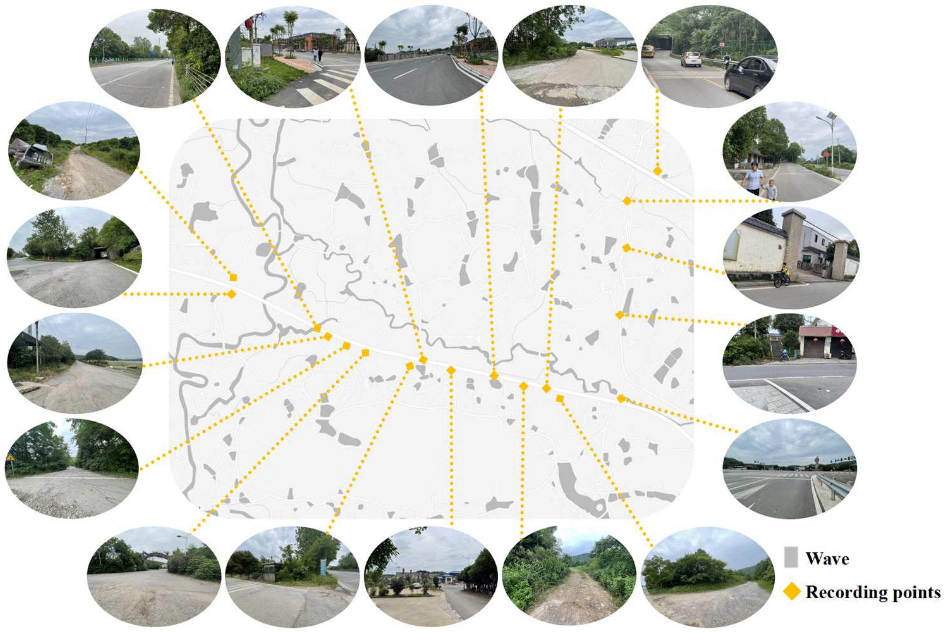


Figure 6. Real photos of the roads with the highest potential traffic frequency in the study area.

3.2. Analysis of Environmental Safety Perception Factors for Independent Travel Paths for Left-Behind Children

Based on the questionnaire survey, Pearson correlation analysis, stepwise regression analysis, and entropy weighting method, we identified the relevant factors that influence the perception of road safety in independent travel by left-behind children.

3.2.1. Reliability and Validity Test of Questionnaire

We analyzed the reliability and validity of the 200 offline questionnaires and 100 online questionnaires collected. The results showed that the reliability of the data was high, and the data could be used for further analysis [49,50]. According to the questionnaire reliability and validity analysis, the 100 offline questionnaires had a reliability coefficient value of 0.950 and a validity index KMO value of 0.929. The 200 offline questionnaires had a reliability coefficient value of 0.679 and a KMO value of 0.680 for the effectiveness index.

3.2.2. Screening Factors for Left-Behind Children's Perception of Road Safety during Independent Travel

First, we screened 100 online questionnaires and 200 offline questionnaires for this part of the study. A Pearson correlation analysis was performed on 100 online questionnaires in which guardians' choice of road safety in the study area was taken as a dependent variable and their assessment of the influence factor on road safety was taken as an independent variable [51,52]. The results of the online questionnaire analysis showed that the p values of the plant density, recognizable signs, turning angle, road slope, electronic tools, social concerns, and monitoring facilities indices were less than 0.05, showing a significant negative correlation (Table 4).

A Pearson correlation analysis was performed on 200 offline questionnaires, where the choice of road safety in the study area by left-behind children and their guardians was taken as the dependent variable and their assessment of the influence factor on road safety was taken as the independent variable. The analysis of the offline questionnaires showed that the p-values of the plant density and road scale indices were less than 0.05, indicating a significant positive correlation; the p value of the electronic tools index was less than 0.05, presenting a significant negative correlation (Table 5). The p-value as a statistical metric is used to judge whether the correlation between two variables is significant or not. The correlation coefficient can be considered significant when the p-value is smaller than the significance level. In practice, it is generally believed that a correlation coefficient can be considered significant if its p-value is less than 0.05, and more significant if it is less than 0.01.

Table 4. Pearson correlation analysis results for 100 online questionnaires on factors affecting perception of road safety.

Influencing Factor	p-Value	Correlation Coefficient
Plant density	0.010	−0.257 **
Recognizable signs	0.018	−0.236 *
Turning angle	0.045	−0.201 *
Road slope	0.017	−0.239 *
Electronic tools	0.001	−0.321 **
Social concerns	0.009	−0.260 **
Monitoring facilities	0.000	−0.354 **

* $p < 0.05$, ** $p < 0.01$.

Table 5. Pearson correlation analysis results of 200 field surveys on factors affecting road safety perception.

Influencing Factor	p-Value	Correlation Coefficient
Plant density	0.001	0.226 **
Road scale	0.017	0.169 *
Electronic tools	0.045	−0.142 *

* $p < 0.05$, ** $p < 0.01$.

Second, 71 out of 100 people who responded to the online survey said the road was safe. The road was considered safe by 120 out of 200 people who responded to an offline survey. The guardians' choice of road safety in the study area was used as a dependent variable in 71 online questionnaires, and their assessment of the influence factor on road safety was used as an independent variable in a stepwise regression analysis [53]. The results of the online questionnaire analysis showed that the regression coefficients of the dangerous animals and stranger indices were less than 0.01, yielding a significant positive correlation (Table 6).

Table 6. Results of a stepwise regression analysis of an online questionnaire on regional road safety.

	Regression Coefficient	95% CI	VIF
Constant	1.000 ** (2,201,030,961,016,510.750)	1.000~1.000	-
Dangerous animals	0.000 ** (5.540)	0.000~0.000	1.094
Strangers	0.000 ** (4.507)	0.000~0.000	1.094
Sample size	71		
R^2	null		
Adjust R^2	null		
F value	F (2,68) = −34.000, p = null		

Dependent variable: road safety for left-behind children traveling alone in the study area. D-W value: 2.209. ** $p < 0.01$ t-values in parentheses.

Stepwise regression analysis was performed on 120 offline questionnaires, where the choice of road safety on left-behind children and their guardians in the study area was taken as the dependent variable and their assessment of the influence factor on road safety was taken as the independent variable. The results of the offline questionnaire analysis showed that the regression coefficient p value of the enclosure type index was less than 0.01, which was a significant negative correlation (Table 7).

Table 7. Results of a step-wise regression analysis of a field survey questionnaire on regional road safety.

	Regression Coefficient	95% CI	Collinear Diagnosis VIF	Tolerance
Constant	1.000 ** (1,352,507,433,325,933.750)	1.000~1.000	-	-
Internal corner space	−0.000 ** (−4.405)	−0.000~−0.000	1.051	0.951
Sample size		120		
R^2		null		
Adjust R^2		null		
F value		F (2,117) = −58.500, p = null		

Dependent variable: road safety for left-behind children traveling alone in the study area. D-W value: 0.350. ** $p < 0.01$ t-values in parentheses.

A step-by-step regression analysis was performed on 80 offline questionnaires with the choice of road insecurity in the study area for left-behind children and their guardians as the dependent variable and their assessment of factors affecting road safety as the independent variable. The regression coefficient p value of the internal corner space index was less than 0.05, which produced a significant negative correlation (Table 8).

Table 8. Results of a step-wise regression analysis of a field survey questionnaire on road insecurity in the study area.

	Regression Coefficient	95% CI	Collinear Diagnosis VIF	Tolerance
Constant	2.000 ** (530,879,512,148,717.813)	2.000~2.000	-	-
Enclosure type	−0.000 * (−2.206)	−0.000~−0.000	1.028	0.972
Sample size		80		
R^2		null		
Adjust R^2		null		
F value		F (3,76) = −25.333, p = null		

Dependent variable: road safety for left-behind children traveling alone in the study area. D-W value: 0.322. * $p < 0.05$, ** $p < 0.01$ t-values in parentheses.

Finally, we applied the random forest algorithm of machine learning to perform data splitting and hyperparameter tuning on the data affecting the road safety perception factors of left-behind children in the study area and to compute the mean decrease accuracy (MDA) and weights of the road safety perception influence factors.

The results show that our constructed learning model works well with Receiver Operating Characteristic Curve (ROC) and Area Under Curve (AUC), and the optimal hyperparameters are mtry = 2, minnode = 21, and trees = 1000 (Figures 7 and 8). The weights of the road safety perception factors are dangerous animals: 0.024532451; strangers: 0.025875346; monitoring facilities: 0.034379649; enclosure type: 0.043407716; internal corner space: 0.049189569; road slope: 0.07319653; recognizable signs: 0.083148354; road scale: 0.098218569; social concerns: 0.107460235; plant density: 0.140429783; turning angle: 0.140834306; and electronic tools: 0.179327493 (Figure 9 and Table 9).

3.2.3. Analysis of Differences in Security Perception between the Left-Behind Child Group and the Guardian Group

We used independent sample t-tests to investigate the differences in road safety perception factors between left-behind children and guardians of different genders and ages. The results of Table 10 show that there are significant differences between left-behind children and guardians for plant density, turning angle, internal corner space, road scale, strangers, social concerns, and monitoring facilities ($p < 0.05$). The results of Table 11 show that there is no significant difference between male left-behind children and female left-behind children in road safety perception factors ($p > 0.05$). The results of Table 12 show that there are significant differences between left-behind children of different ages for internal corner space, strangers, and electronic tools ($p < 0.05$).

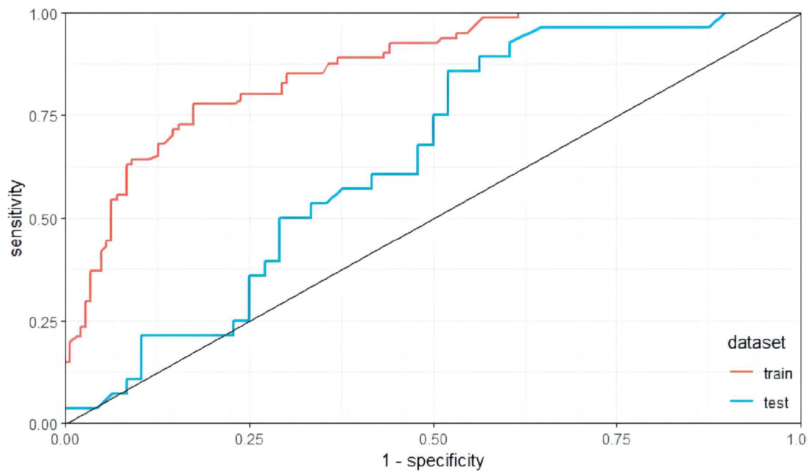


Figure 7. Model evaluation of machine learning algorithms.

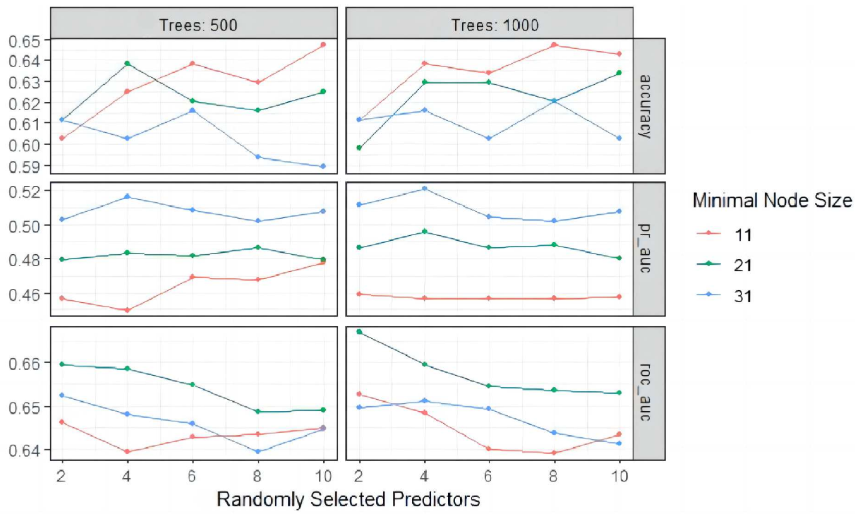


Figure 8. Hyperparameter determination for machine learning algorithms.

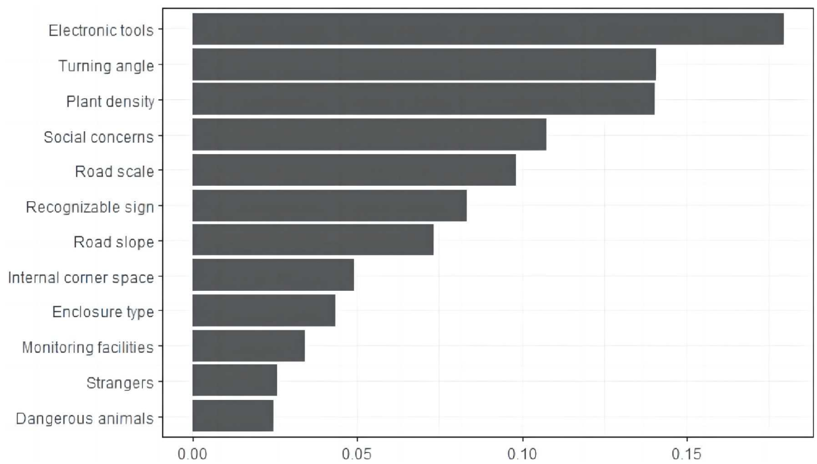


Figure 9. Importance ranking of the weighting of perceived factors for road safety.

Table 9. Results of the random forest algorithm based on machine learning for road travel safety factor weights.

Influencing Factor	Mean Decrease Accuracy	Weight
Dangerous animals	2.168102094	0.024532451
Strangers	2.286783068	0.025875346
Monitoring facilities	3.038366986	0.034379649
Enclosure type	3.836239636	0.043407716
Internal corner space	4.347221906	0.049189569
Road slope	6.468882858	0.07319653
Recognizable signs	7.348394323	0.083148354
Road scale	8.68025325	0.098218569
Social concerns	9.497003152	0.107460235
Plant density	12.41074979	0.140429783
Turning angle	12.44650032	0.140834306
Electronic tools	15.84840911	0.179327493

Table 10. Independent sample *t*-test of road safety perception factors for left-behind children and their guardians.

	Left-Behind Children and Guardians (Mean ± Standard Deviation)		*t*	*p*
	1 (n = 78)	2 (n = 42)		
Plant density	1.385 ± 0.725	4.357 ± 0.906	−19.599	0 ***
Recognizable signs	3.218 ± 1.065	3.214 ± 1.116	0.018	0.986
Turning angle	2.423 ± 1.013	3.262 ± 1.061	−4.256	0 ***
Enclosure type	4 ± 0.456	4.071 ± 1.156	−0.482	0.631
Internal corner space	4.244 ± 0.84	3.762 ± 1.428	2.327	0.022 *
Road scale	2.423 ± 0.987	4.333 ± 0.816	−10.716	0 ***
Road slope	3.141 ± 1.181	3.381 ± 1.058	−1.1	0.274
Dangerous animals	3.41 ± 0.946	3.738 ± 0.885	−1.852	0.067
Strangers	3.987 ± 0.497	3.738 ± 0.828	2.06	0.042 *
Electronic tools	3.974 ± 0.394	3.857 ± 0.718	1.157	0.25
Social concerns	4.013 ± 0.522	3.667 ± 0.874	2.716	0.008 **
Monitoring facilities	4.333 ± 0.832	3.738 ± 0.885	3.655	0 ***

* p, < 0.05, ** $p < 0.01$, *** $p < 0.001$.

Table 11. Independent sample *t*-test of road safety perception factors for male and female left-behind children.

	Male Left-Behind Children and Female Left-Behind Children (Mean ± Standard Deviation)		*t*	*p*
	1 (n = 62)	2 (n = 58)		
Plant density	2.5 ± 1.637	2.345 ± 1.628	0.52	0.604
Recognizable signs	3.161 ± 1.089	3.276 ± 1.073	−0.58	0.563
Turning angle	2.661 ± 1.159	2.776 ± 1.044	−0.568	0.571
Enclosure type	4.032 ± 0.701	4.017 ± 0.848	0.106	0.916
Internal corner space	4.097 ± 0.987	4.052 ± 1.22	0.223	0.824
Road scale	3.161 ± 1.296	3.017 ± 1.318	0.604	0.547
Road slope	3.403 ± 1.137	3.034 ± 1.123	1.785	0.077
Dangerous animals	3.419 ± 1.001	3.638 ± 0.852	−1.284	0.202
Strangers	3.855 ± 0.649	3.948 ± 0.633	−0.798	0.427
Electronic tools	3.887 ± 0.63	3.983 ± 0.397	−0.987	0.325
Social concerns	3.839 ± 0.772	3.948 ± 0.575	−0.877	0.382
Monitoring facilities	4.032 ± 1.008	4.224 ± 0.75	−1.177	0.242

Table 12. Independent sample *t*-test of road safety perception factors in left-behind children aged 6–12 and 13–16.

	Left-Behind Children Aged 6–12 and 13–16 (Mean ± Standard Deviation)		t	p
	1 (n = 72)	2 (n = 48)		
Plant density	2.278 ± 1.594	2.646 ± 1.669	−1.216	0.226
Recognizable signs	3.333 ± 0.979	3.042 ± 1.202	1.458	0.147
Turning angle	2.681 ± 1.059	2.771 ± 1.171	−0.438	0.662
Enclosure type	4.097 ± 0.609	3.917 ± 0.964	1.258	0.211
Internal corner space	4.361 ± 0.81	3.646 ± 1.329	3.663	0 ***
Road scale	3.042 ± 1.358	3.167 ± 1.226	−0.513	0.609
Road slope	3.181 ± 1.117	3.292 ± 1.184	−0.521	0.603
Dangerous animals	3.597 ± 0.85	3.417 ± 1.048	1.037	0.302
Strangers	4.028 ± 0.443	3.708 ± 0.824	2.75	0.007 **
Electronic tools	4.014 ± 0.205	3.812 ± 0.79	2.066	0.041 *
Social concerns	3.958 ± 0.426	3.792 ± 0.944	1.313	0.192
Monitoring facilities	4.208 ± 0.749	4 ± 1.072	1.253	0.213

* p, < 0.05, ** p < 0.01, *** p < 0.001.

Based on the vision permeability analysis, as shown in Figures 10 and 11, it was found that the mean value of the child's assessment of the plant density index was 1.38462 and the mean value of the guardian's assessment was 4.35714, showing a significant difference. The mean was 2.2778 to 2.64583 for children of different genders and ages, with no significant differences. Second, the mean value of the recognizable signs index evaluated by children and guardians was 3.21429 and 3.21795, with no significant differences. The mean was 3.16129 to 3.33333 for children of different genders and ages, with no significant difference. Moreover, the mean value of the turning angle index was 2.42308 for children and 3.2619 for guardians, showing a significant difference. The mean for children of different genders and ages was 2.66129 to 2.77586. There was no significant difference.

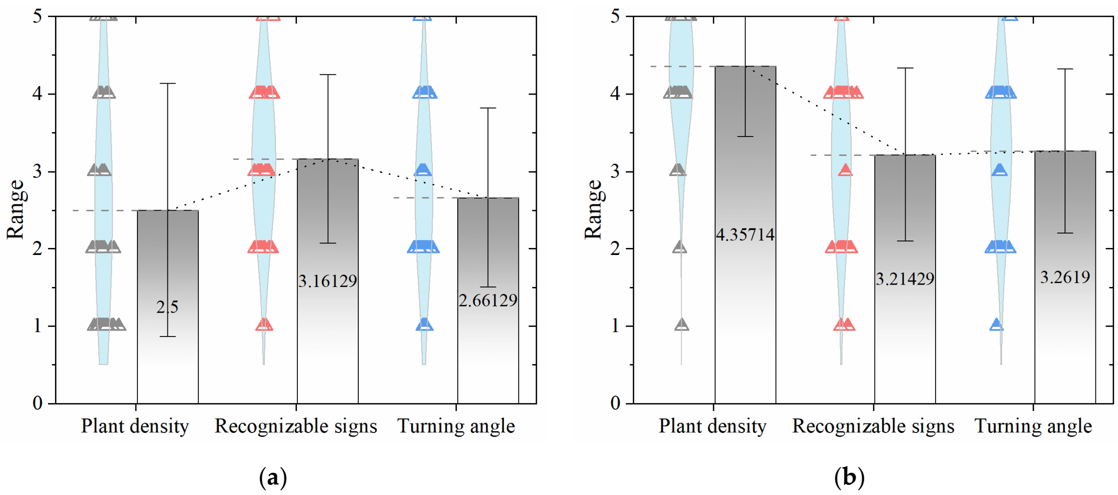


Figure 10. Analysis of vision permeability of the left-behind children and guardians. (**a**) Children; (**b**) guardians.

Based on the interface dissociability analysis, as shown in Figures 12 and 13, children and guardians rated the enclosure type index at a mean of 4 and 4.07141, with no significant differences. The internal corner space index had a mean value of 3.7619 to 4.24359, which was significantly different. The mean value of enclosure type index evaluations for children of different genders and ages was 3.91667 to 4.09722, with no significant differences. The mean value of the internal corner space index assessment was 3.644583 to 4.36111, with significant differences between the mean value for children aged 6–12 and children aged 13–16.

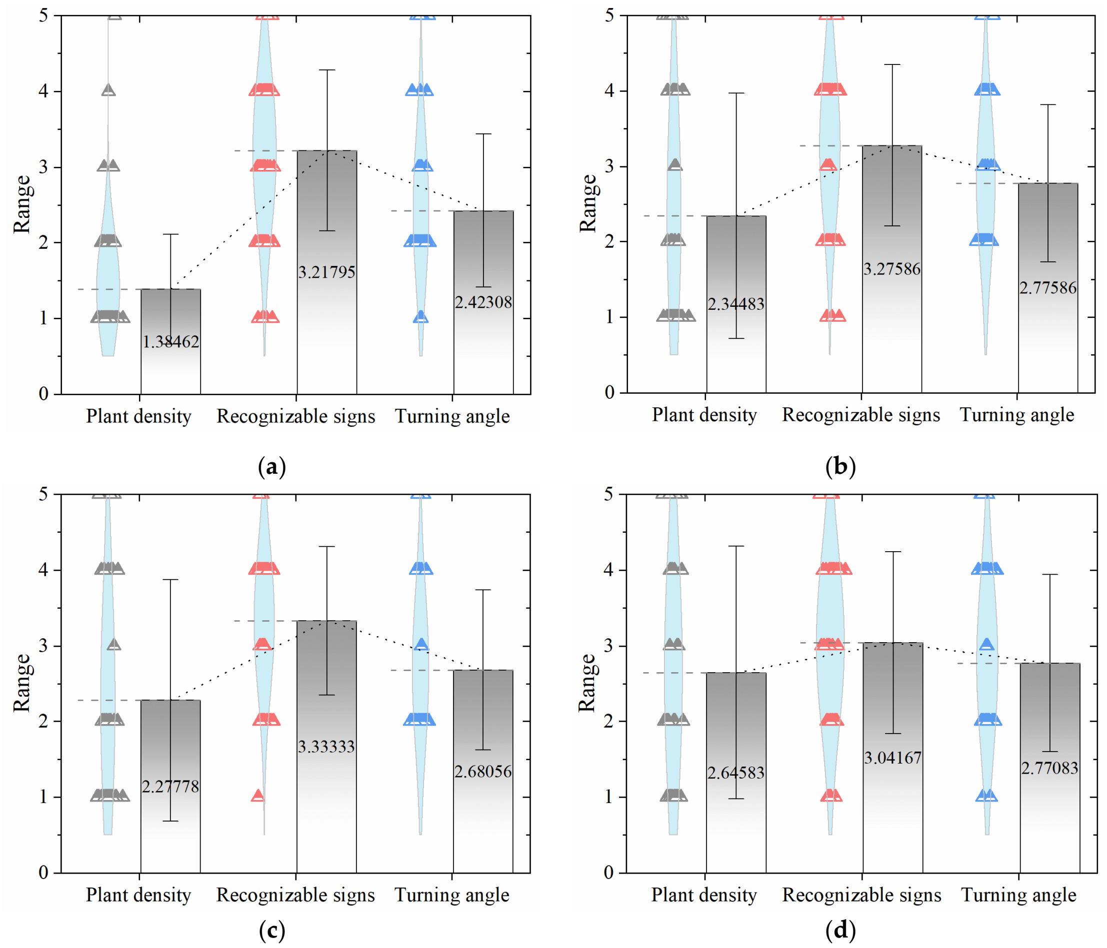


Figure 11. Analysis of vision permeability of the left-behind children groups. (**a**) Male left-behind children; (**b**) female left-behind children; (**c**) left-behind children aged 6–12; (**d**) left-behind children aged 13–16.

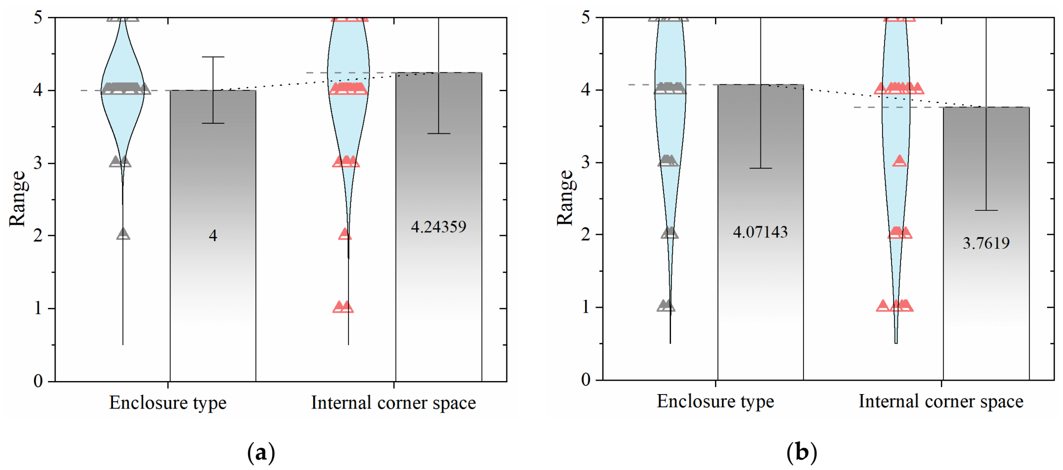


Figure 12. Analysis of interface dissociability of the left-behind children and guardians. (**a**) Children; (**b**) guardians.

Based on the travel accessibility analysis, as shown in Figures 14 and 15, it was found that the mean value of the child's assessment of the road scale index was 2.42308 and the mean value of the guardian's assessment was 4.33333, which was a significant difference. The mean value of the road slope index for children and guardians was 3.14103 to 3.38095, with no significant difference. In addition, children of different genders and ages showed no significant difference in the mean value of the road scale index assessment, at 3.0 to 3.1, or in the mean value of the road slope index evaluation, at 3.03448 to 3.40323.

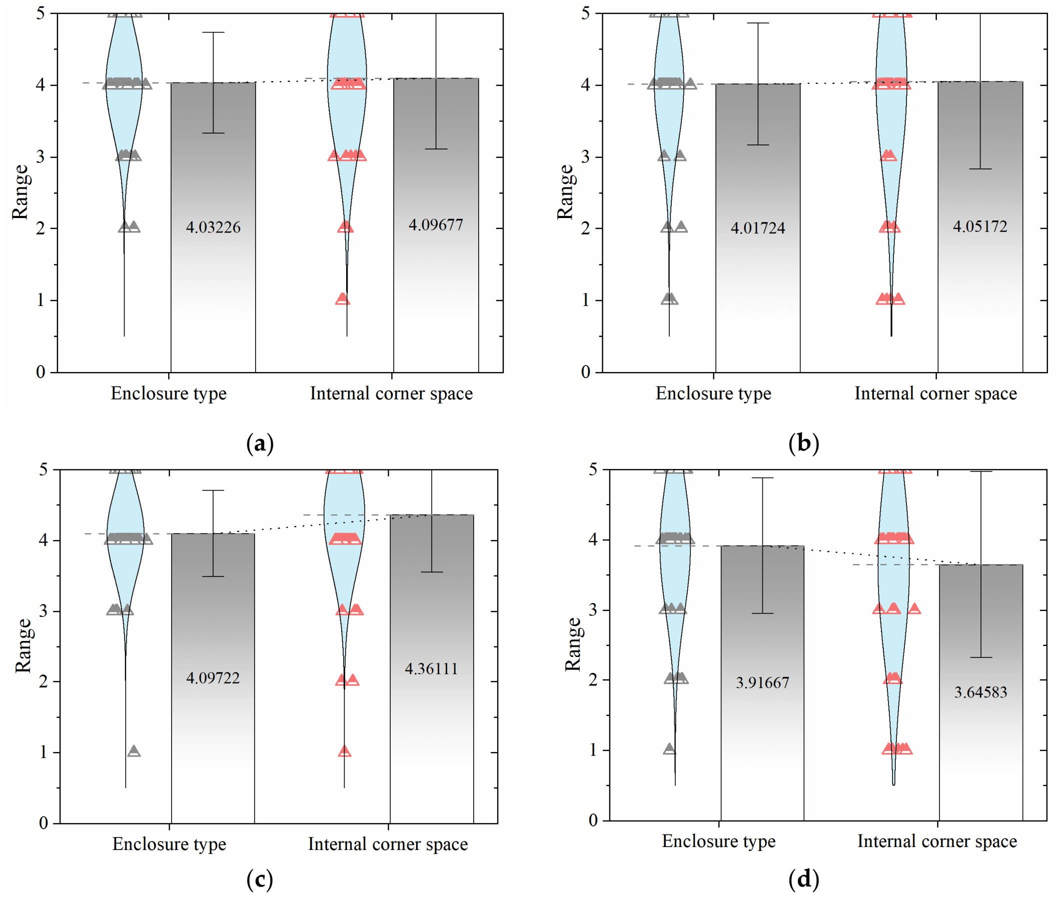


Figure 13. Analysis of interface dissociability of the left-behind children groups. (**a**) Male left-behind children; (**b**) female left-behind children; (**c**) left-behind children aged 6–12; (**d**) left-behind children aged 13–16.

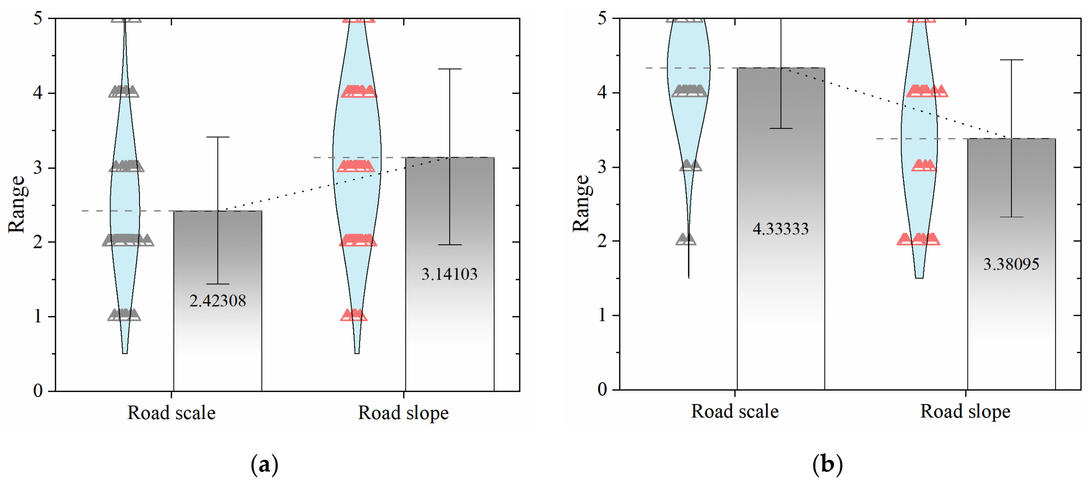


Figure 14. Analysis of travel accessibility of the left-behind children and guardians. (**a**) Children; (**b**) guardians.

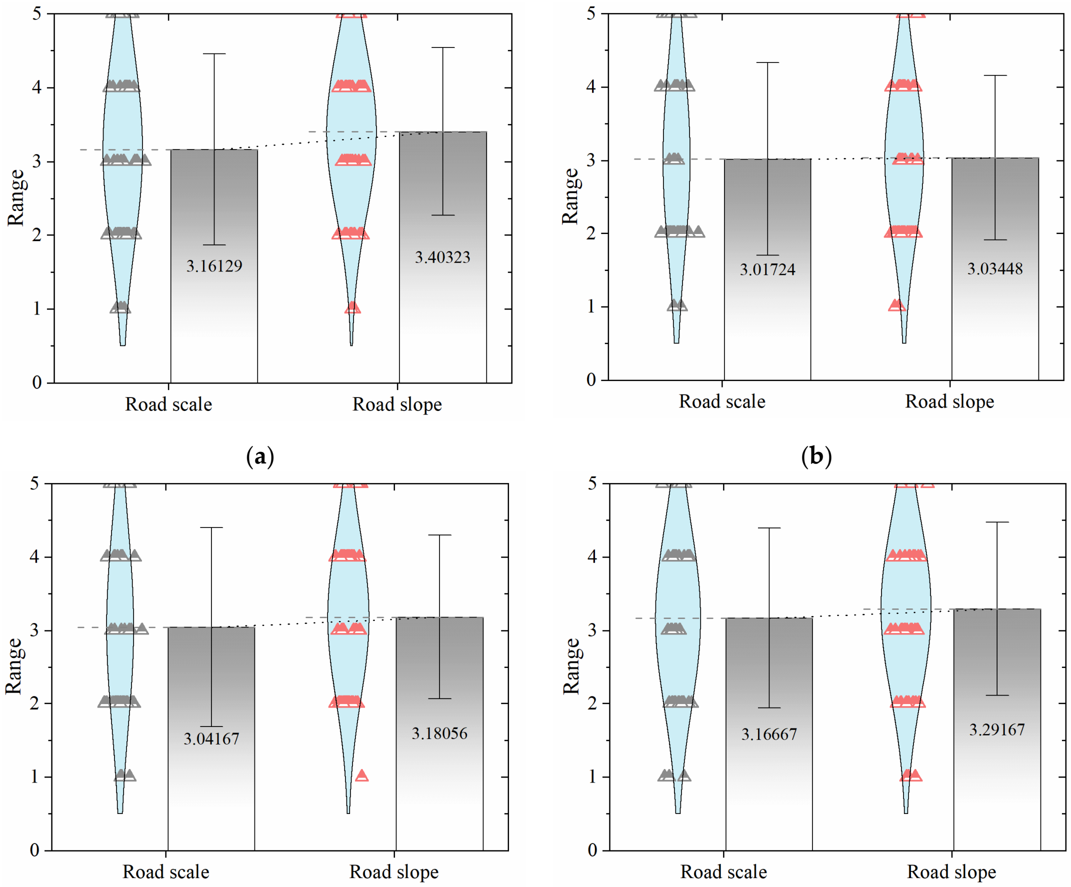


Figure 15. Analysis of travel accessibility of the left-behind children groups. (**a**) Male left-behind children; (**b**) female left-behind children; (**c**) left-behind children aged 6–12; (**d**) left-behind children aged 13–16.

Based on the neighborhood shelter analysis, as shown in Figures 16 and 17, it was found that the mean value of the child and guardian's assessment of the dangerous animals index was 3.1026 to 3.7381. The average stranger score was 3.7381 to 3.98718. The average electronic tools score was 3.85714 to 3.97436. The average social concerns score was 3.6667 to 4.01282. The average monitoring facilities score was 3.7383 to 4.333, and the difference was not significant. In addition, the mean value of the dangerous animals index assessment for children of all genders and ages was 3.41935 to 3.63793, the stranger index was 3.70833 to 4.02778, the electronic tools index was 3.8125 to 4.01389, and the social concerns index was 3.79167 to 3.95833. The mean value of the monitoring facilities index was 4 to 4.22414. The mean values tended to be essentially the same, and there were no clear differences.

In summary, there was a significant difference in the mean value of evaluation between left-behind children and their guardians. For plant density, turning angle, enclosure type, and road scale, the road safety perception of left-behind children was higher than that of their guardians. In addition, there were some non-significant differences in the mean values of the assessments among children of different genders and ages. For enclosure type, left-behind children aged 6–12 had a higher perception of safety than left-behind children aged 13–16. Among left-behind children of different ages and genders, the safety perceptions of the dangerous animals, strangers, electronic tools, social concerns, and monitoring facilities indicators were different. Left-behind children aged 6–12 had higher security perceptions than left-behind children aged 13–16, and male left-behind children had lower security perceptions than female left-behind children.

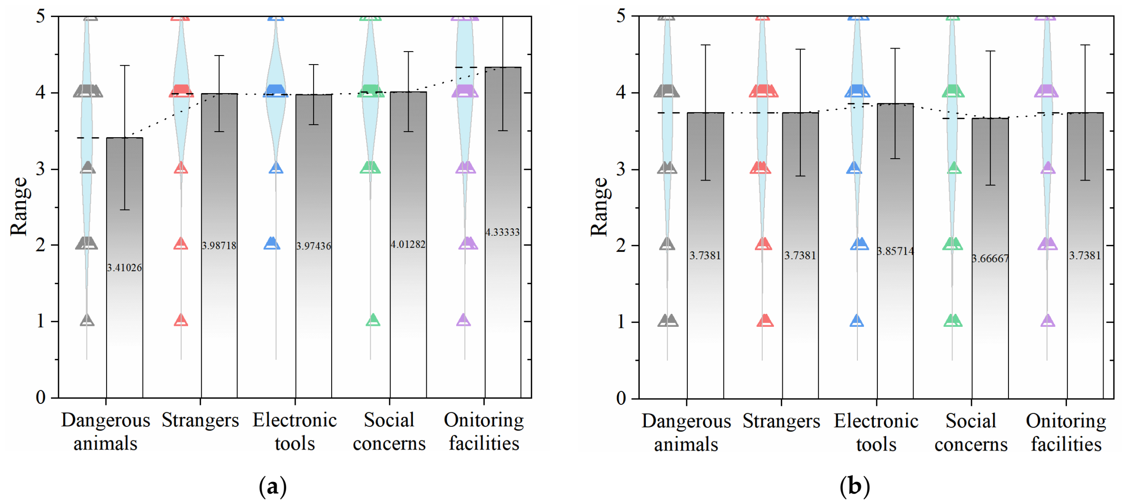


Figure 16. Analysis of neighborhood shelter of the left-behind children and guardians. (**a**) Children; (**b**) guardians.

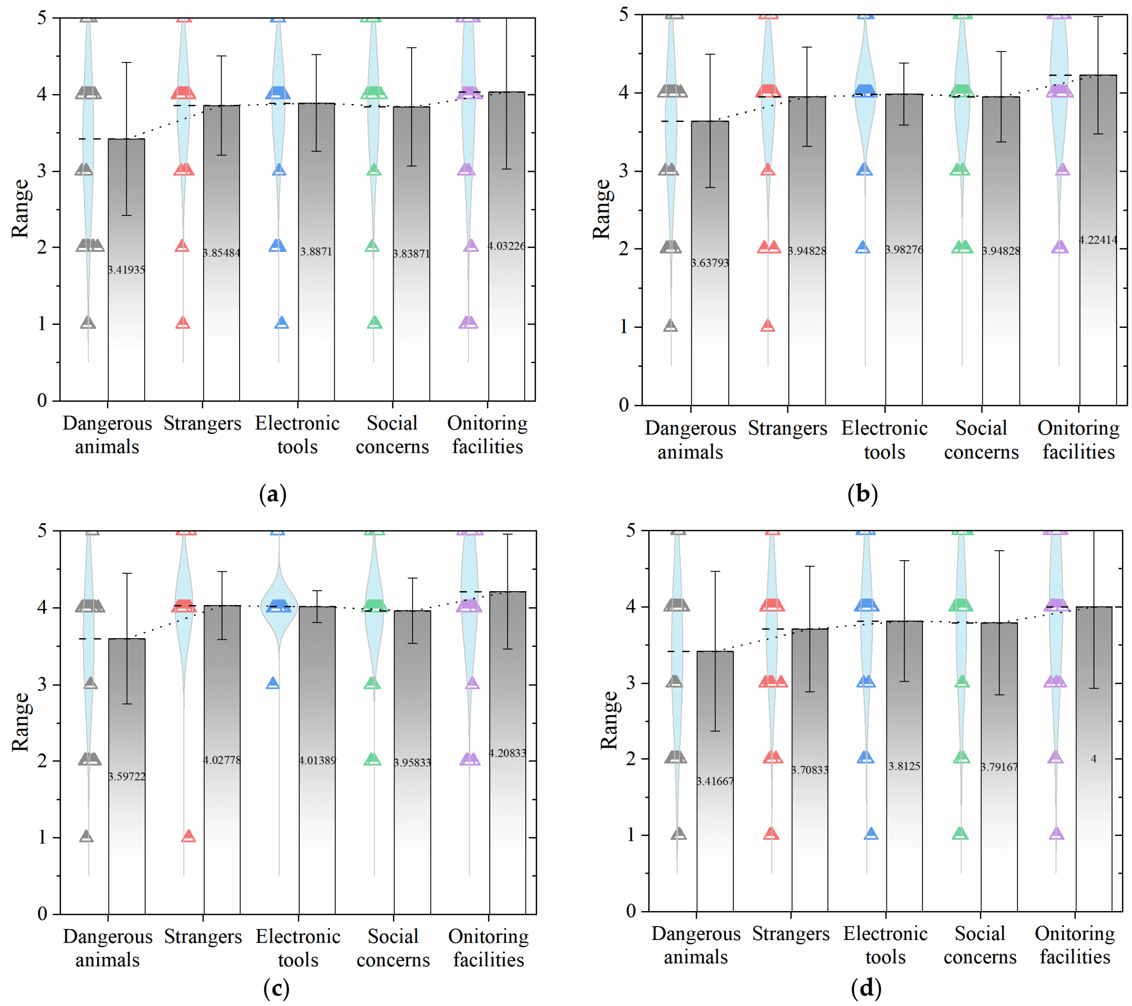


Figure 17. Analysis of neighborhood shelter of the left-behind children groups. (**a**) Male left-behind children; (**b**) female left-behind children; (**c**) left-behind children aged 6–12; (**d**) left-behind children aged 13–16.

4. Discussion

4.1. The Tendency of Left-Behind Children to Choose Independent Paths of Travel

Previous research has shown that 62% of adults would restrict children's independent travel to places < 500 m from home, and 74% would restrict independent outdoor play < 500 m from home [37]. This is different from our findings. Our analysis of roads in the study area shows that the distances left-behind children travel independently are highly uncertain and often exceed the distance allowed by their guardians. Left-behind children tend to choose the roads they travel frequently. It is important to note that although guardians excessively restrict the distance and time that left-behind children can travel, left-behind children often sneak out to play alone.

4.2. Differences in Road Safety Perception between Left-Behind Children and Their Guardians

The relevance index, as an independent variable, showed a significant correlation with the dependent variable of road safety for left-behind children, which validated the index. First, the study found significant differences in perceptions and assessments of road safety between children and their guardians. Children's perceptions of road safety for independent travel were higher than their guardians' perceptions. Guardians were more concerned about the safety of children's travel environments, which was consistent with the existing literature. Guardians will restrict children from traveling alone in environments where they think accidental injuries are possible [54]. The difference in safety perception between the different groups of children was not significant, which was different from the existing literature. The outdoor behaviors of children of different ages (infants, preschool children, and school-age children) tend to be specific [55]. However, this study focused primarily on left-behind children aged 6–16 years, and the left-behind children interviewed were relatively similar in age. Both the children and the caregivers agreed that the children could clearly spot the warning signs along the road in danger areas. This was consistent with the existing literature showing that roadside traffic lights and speed limit signs are conducive to the safety of children's independent travel [56]. Left-behind children reported finding it easy to observe the traffic in front of them at intersections despite dense trees and plants, and on roads with sharp turns, because they believe that cars must honk when passing such roads. The guardians suggested the contrary. Unlike in the existing literature, landscape buffer zones and trees increased guardians' willingness to allow children to travel independently [57,58]. The reason for this may have been that if the height of the left-behind child is lower than the height of the plant, a dense bush may block the vision of the child and the driver, resulting in visual blindness. Therefore, for roads with sharp turns and high plant density, the village government should plant low plants below the average height of left-behind children in the future and organize staff to prune them regularly to ensure the good visual permeability of roads.

Secondly, both the left-behind children and the guardians believed that the child would feel safe when passing through roads with buildings on one side, walls, and roads connected with courtyards of buildings. This was consistent with the existing literature, showing the integrity of effective road facilities helps to enhance the safety perception of children on the road [29]. In addition, left-behind children aged 6–12 had a higher perception of safety than 13–16-year-olds when traveling on roads connected to construction yards. However, through field interviews, we found that overly closed roads, such as tunnels closed on three sides, inhibited the sense of travel security of left-behind children. Left-behind children tend to choose roads that connect to open-plan building courtyards. However, roads connected by enclosed buildings and courtyards had a weaker choice intention for children. As a result, those in charge should install guardrails as far as possible from water on roads, using single-piece shapes and smooth materials to limit children's climbing behavior. At the same time, a building courtyard beside a connecting road is open and forms a "connecting space" between the building and the road, which serves as the sidewalk for left-behind children to travel on.

In addition, left-behind children and their guardians rated children's safety differently when traveling on roads with heavy gradients and unattended vehicles; guardians' perception of road safety was lower. They were extremely concerned about accidents involving children on roads where there is no diversion from traffic. This was consistent with the existing literature showing that caregivers are more concerned about road safety than children [59]. Children of all genders and ages were believed to be less likely to be injured in accidents on roads where people and vehicles are separated. This was different from the existing literature showing children are prone to accidents on the road where people and cars are mixed [60]. The reason for this may be that left-behind children trust vehicles to identify them accurately and actively avoid them. Therefore, authorities should demarcate people and vehicles on major roads in rural areas and impose speed limits for motor vehicles, which can help reduce the accident rate of collisions between moving vehicles and left-behind children.

Finally, children of different genders and ages and their guardians rated children's safety as low when passing by animals such as stray dogs and cats, strangers, and perpetrators of bullying. This was consistent with the existing literature, which shows that neighborhood environment security can effectively enhance children's willingness to travel independently [31,61]. It may be that left-behind children tend to avoid such roads because they think they will suffer personal harm when traveling on them, such as animal bites, bullying, and abduction by strangers. In addition, when children wear phone watches, mobile devices, and installed monitoring devices, a strong sense of safety during road travel emerges. This was consistent with the existing literature. Children can quickly contact their caregivers when wearing communication devices, and perfect road monitoring can track children's travel paths and reduce accidental injuries of children on roads [62]. However, in field interviews, some of the left-behind children believed that wearing a communication device limited their ability to travel independently, as caregivers could be alerted to the device while the child was traveling. Therefore, the government should improve surveillance facilities on rural roads, issue regulations on rural dog breeding, and urge villagers to leash their dogs. At the same time, workers should be organized to collect stray dogs, cats, and other animals in rural areas for centralized management, which will help reduce the concerns of guardians and improve the perception of road safety among left-behind children as they travel independently.

4.3. Limitations and Further Research

There were certain limitations to this study. First, the sample size was small, as only four rural areas in Wangcheng District of Changsha City were included, and only data on the independent travel of left-behind children in April and May were collected from field observations. However, the independent travel activities of left-behind children may vary depending on weather or other environmental factors, which may limit the results of the analysis. Second, the age range of the group surveyed was limited. This study focused on left-behind children aged 6–16 years, as children aged 0–6 are often accompanied by guardians and are rarely allowed to travel independently. Left-behind children aged 17–18 tend to act as adults in terms of physical and mental development and road environment perception, and they have a strong sense of safety. Therefore, no data were collected on left-behind children aged 0–6 and 17–18 years. Third, interview-based questionnaires are relatively subjective. Although several questionnaires were conducted, online questionnaires can only be subjectively assessed through photographs, which may contain errors. In addition, due to the anonymous nature of the data collection, younger left-behind children, especially those who completed the questionnaire with the help of their parents, may have worried that their parents would be blamed or punished for their behavior, and thus failed to answer with true experiences of the dangers and injuries they could suffer when traveling alone. It is important to note that the study and its results were limited to rural areas similar to the villages in the study region. Since there are many types of rural areas, such as suburban rural areas, urban villages, traditional villages, smart villages, and so on, they often have certain differences. These differences may be reflected not only in economic, cultural, and other aspects, but also in the overall spatial characteristics of the village and the behavioral patterns of the villagers.

Despite these limitations, this study achieved a systematic analysis of the road safety of rural left-behind children traveling independently, indicating that there are still safety risks for this group, and more attention is needed. It is expected that future studies will extend the coverage of the sample and fully consider the characteristics of the independent travel of left-behind children in each season and under different weather conditions. More research into the family structure of left-behind children could also be supplemented with discussion groups for children. These elements will help to improve the accuracy of the study.

Significantly, multicollinearity often causes parameter estimates to become unstable and the effect of the respective variables on the dependent variables to be uncertain. If it is shown that the model has multicollinearity, then we can eliminate the variables that cause the multicollinearity via a stepwise regression analysis, and we can also transform the original model into a difference model, thus effectively eliminating the multicollinearity in the original model. We can also reduce the variance in the parameter estimator via Ridge Regression, eliminating the multicollinearity consequences. Therefore, we should pay more attention to the multicultural nature of linear regression models in follow-up studies.

5. Conclusions

This study explored the safety of independent road travel for left-behind children in rural China. Based on an investigation of four rural areas in the Wangcheng District of Changsha City, China, this paper used spatial syntax tools and linear regression methods to analyze roads with a high frequency of independent travel by left-behind children. In addition, factors affecting the perception of road safety by left-behind children for independent travel were identified through Pearson correlation analysis, stepwise regression analysis, and machine learning.

The conclusions were as follows: First, plant density, turning angle, road scale, road slope, recognizable signs, internal corner space, dangerous animals, enclosure type, electronic tools, monitoring facilities, strangers, and social concerns were major factors in the perception of road safety for left-behind children traveling independently. Attention to and the optimization of these factors could enhance the safety of the road environment for left-behind children to travel independently. Second, the road safety perceptions of groups of left-behind children and caregivers differed significantly. The road safety perception of left-behind children was significantly higher than that of guardians, and the lower safety perception of guardians may somewhat inhibit the independent travel activities of left-behind children. In addition, there were differences, though not significant, in road safety perceptions among left-behind children of different genders and ages. Younger left-behind children had a higher perception of road safety than older left-behind children. Female left-behind children had a higher perception of safety than male left-behind children. These findings may provide inspiration for policymakers to formulate policies and optimize rural road environments to build a safe and healthy growth environment for rural left-behind children, a vulnerable group.

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