脆弱性と抵抗性に着目した自転車盗難に対する防犯力の発見

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https://doi.org/10.15017/1485045

出版情報：都市・建築学研究. 25, pp.25-33, 2014-01-15. 九州大学大学院人間環境学研究院都市・建築学部門

脆弱性と抵抗性に着目した自転車盗難に対する防犯力の発見

Discovery of Defensibility against Bicycle Theft Focusing on Vulnerability and Resistance in Urban Area

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Corresponding to the increasing number of bicycle theft, bicycle theft prevention ideas are becoming more required to be incorporated into city planning. While, some papers have clarified the spatial vulnerability of bicycle parking places against bicycle theft, it is also necessary to understand the resistance in order to describe the "defensibility" of bicycle parking places against bicycle theft. This paper aims to describe the "defensibility" with the factors of both vulnerability and resistance. Utilizing the results of previous studies, a set of indicators were prepared to conduct on-the-spot surveys on bicycle parking places in Kego elementary school district, Fukuoka city. Through logistic regression analyses, the equations of both vulnerability and resistance were obtained. Also, a scatter diagram clarifies the antagonism between vulnerability and resistance, and is able to detect the latent vulnerable spots. In the end, appropriate improvements on some types of vulnerable bicycle parking places categorized based on the balance of two factors are suggested.

Keywords: CPTED, Defensible Space, Bicycle Theft, Spatial Design, Defensibility
CPTED, 守りやすい空間, 自転車盗難, 空間デザイン, 防犯力

1. Introduction

1.1 Research Background

Nowadays, a number of urban problems have emerged into our urban life with the advance of urbanization and modernization. This causes citizens to be more troubled by crime and disturbs or even threatens the growth of cities. For examples, while the numbers of motorcycle and car thefts are decreasing, the number of bicycle thefts does not follow the same trend from 2002 to 2011(Fig. 1), even though the Police have tried to encourage people to be careful of bicycle theft and many tools to prevent bicycle theft have been produced. Given this issue, under the social movement of bicycle use expansion due to the perceived negative environmental impact caused by vehicles, urban planning aiming at bicycle theft prevention is increasingly called for in Japan.

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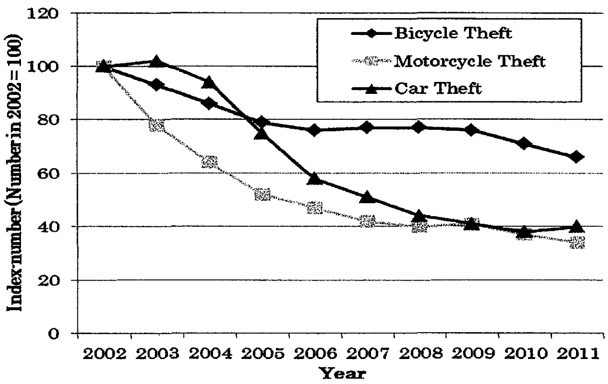


Fig.1. Index-number of Reported Vehicle Thefts in Japan

1.2 Previous Studies

Since when "Defensible Space (Newman, 1996)," "CPTED (Crime Prevention through Environmental Design) (Jeffery, 1971)" and "Situational Crime Prevention (Clarke, 1983)" were imported into the research field of crime and crime prevention in Japan, it had led to the participation of many other study fields, such as architecture and urban planning, and many studies have focused on the relationship between the occurrence of crimes and external and spatial factors.

Starting with the study conducted by Omata (1998), analyzing the relationship between the occurrence of crimes and environmental/psychological aspects, a bunch of researches have been conducted in order to clarify the relationship between crimes and the characteristics of cities and districts by focusing on the physical environment. For example, Kashiwara et al. (1996) focuses on spatial factors within a city in order to examine whether they are related to the occurrence of crimes on convenience stores or not. Also, as an example of the studies focusing on the relationship between the occurrence of situational crimes and environmental design, Kashibayashi et al. (2008) indicates the common and different features of two places where many bicycle thefts had taken place while mentioning the importance of considering the public exposure of parking lots for bicycles as one of environmental factors for that may contribute towards bicycle theft.

Moreover, Utsui (2010) clarifies in his study that the density of bicycle theft is related to the location of big commercial buildings and stations.

The studies mentioned above are generally clarifying vulnerability against specific crimes by analyzing crime-related factors and crime occurrence. In the history of the study field on crime and crime prevention, only one variable, vulnerability, has been used to find defensibility. However, crime attempters recognize not only vulnerability but also resistance when they try to commit a crime. Therefore, there is a clear need to handle these two variables to reach to more accurate defensibility.

To meet the demand, our previous paper (Sugino, 2012) clarified the ideation model of bicycle thief and described the implicit reasons why bicycle thefts are not committed in the urban context, which was clarified by analyzing field notes about where bicycles are regularly parked through the application of the integrated methods of contextual inquiry and text mining. As a result, based on the ideation model (Fig. 2), it was revealed that not only target bicycles but also many factors, such as uncritical observers, compatibility between a place and an intended thief, and proximity between a place and possible destinations are considered when bicycle thefts are committed. Since bicycle theft is a crime of opportunity and basically happens in semi-public spaces. Therefore, the techniques mentioned in CPTED, such as installation of surveillance cameras and security machines are thought as effective practices to prevent bicycle theft. However, they are remarkably excluded from the ideation model. That is because these security devices cannot be instantaneous deterrence, and moreover, they can conversely be the sign that there are few people coming around the bicycle parking place.

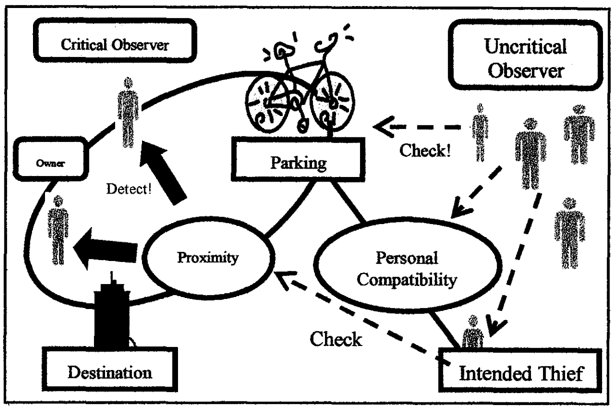


Fig. 2 Ideation Model of Committing Bicycle Theft

Based on the above, the major objective of this research is to produce an equation model of spatial cognition to define defensibility against bicycle theft calculated by the indicators of both vulnerability and resistance extracted from previous studies. Also, utilizing the equation model, the latent vulnerable bicycle parking places which cannot be found by looking at only vulnerability are clarified and examined to be improved for the further urban planning aiming at bicycle theft prevention.

2. Methodology

2.1 Study Target

According to the report of the Police, Fukuoka was ranked No.8 for bicycle thefts and 14,216 bicycle thefts have been reported in Fukuoka in 2012 (Table 1). Also, the number of possession and its number per 100 people are shown in Table 1 based on the data of bicycle possession produced by the Japan Bicycle Promotion Institution. Among the prefectures ranked within 10 for the number of bicycle theft, Fukuoka has a notably small number of possessions per 100 people, and which implies that there are comparatively many people who own a bicycle (or bicycles) and experienced bicycle theft in Fukuoka.

Considering the number of bicycle theft summed up for each elementary-school district reported by the Fukuoka Prefectural Police in 2012, bicycle thefts were concentrated around Tenjin and Hakata areas, the two central areas of Fukuoka City. Among the elementary-school districts which had a lot of bicycle thefts in 2012, 164 bicycles have been stolen in the Kego elementary-school district (Fig. 3) whose ration of bicycle theft is comparatively higher than other districts surrounding the Tenjin and Hakata areas. Also, the district has well-mixed urban functions, such as commercial facilities, offices, schools, residential areas, and public transportation hubs.

Consequently, this district was selected as a suitable area to examine the actual condition of bicycle theft, and there is a clear need to consider bicycle theft preventive urban planning.

2.2 Data of Bicycle Theft in the Target District

In order to conduct this research, the detailed information about bicycle theft in the Kego elementary school district, Fukuoka City, was needed, and it was provided by the Fukuoka Prefectural Police. The data includes all the data of bicycle theft carried out and reported within a 4-year period (from January of 2007 to July of 2010). For each bicycle theft, the specific address, date, time, and category of the place (roadside, parking lot, apartment, etc.) are provided as details.

2.3 Method Flow

At the set out, the temporal trend of bicycle theft in the target district is analyzed to see whether there is specific temporal zone which should be paid attention for prevention or not. Then, utilizing the results of previous studies, a set of indicators were prepared focusing on vulnerability and resistance to conduct on-the-spot surveys on 457 bicycle-parking places in the district.

Based on the result of the on-the-spot survey, some of indicators which have strong relation with the occurrence of bicycle theft are selected. After that, multivariate regression analysis is applied to obtain each regression equation for vulnerability and resistance.

In addition, the equation is utilized to detect potential hot spots and defensible spaces, and clarifies the antagonism between vulnerability and resistance at the same time. Moreover, the antagonism reveals the some kinds of vulnerable spots which have high vulnerability or latently have equilibrium of these two factors.

At last, according to the categorization based on the analysis of the antagonism of the two factors, appropriate improvements on each type of vulnerable bicycle parking places are discussed, and the further crime preventive urban planning method was suggested.

Table 1 Number of Bicycle Theft and Possession

Number of Bicycle Theft (2012)			Number of Possession (2008)	
Rank	Prefecture	Bicycle Theft Reported	Number of Possession	Number of Possession per 100 people (Rank in 47 prefectures)
1	Tokyo	53,184	8,999,000	72.21 (3)
2	Osaka	30,191	6,515,000	75.14 (2)
3	Saitama	24,706	5,436,000	76.92 (1)
4	Kanagawa	20,643	5,315,000	60.41 (7)
5	Chiba	18,890	3,763,000	61.78 (5)
6	Aichi	18,823	4,084,000	56.83 (10)
7	Hyogo	15,930	3,390,000	60.73 (6)
8	Fukuoka	14,216	1,870,000	37.17 (42)
9	Hokkaido	8,810	2,834,000	50.86 (19)
10	Kyoto	7,359	1,656,000	64.72 (4)
–	National Amount	303,745	69,099,000	54.38

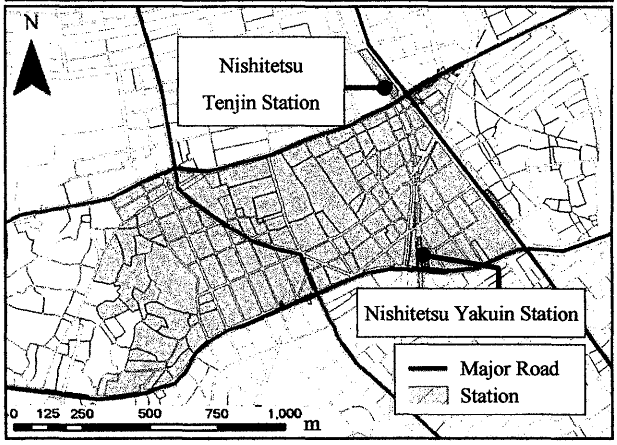


Fig. 3 Kego Elementary-School District

3. Initial Research on Bicycle Theft in the Target District

3.1 Summary of Bicycle Theft Data

Summing up the data of bicycle theft, Fig. 4 shows the number of bicycle theft reported within the Kego elementary school district from the beginning of 2004 to the end of 2012. The district has had in total about 1,279 bicycle thefts, and about 142 bicycle thefts in each year.

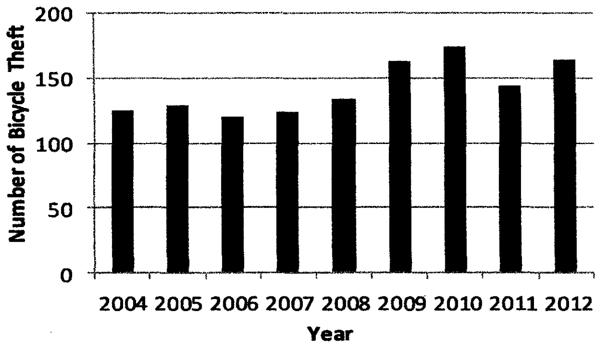


Fig. 4 Bicycle Thefts in the Kego Elementary-School District

In Table 2 which shows the temporal matrix of bicycle theft, there is a specific time zone in which a lot of bicycle thefts are concentrated. Generally, bicycle theft was conducted in the same day-cycle on both weekdays and weekends. From 8:00 to 24:00, bicycle thefts are constantly conducted because there is concentration of target (bicycle) due to people's daytime activities. Also, the twilight time zone (from 18:00 to 20:00) has significant concentration of bicycle theft, and that is assumed to be caused by increase of blind spots which correspondingly appear by the sun setting. Besides, in that time zone, people tend to move from where they have stayed during the day time to their residences or places for evening recreations. Therefore, the demand for bicycles is comparatively increased, and that can be one of the reasons why there is the temporal convergence of bicycle theft.

Consequently, it is suggested that prevention methods must be integrated with the environment in which people do some activities around, and focus on the specific time zone (from 18:00 to 20:00) which bicycle theft occurrence converged in the target district.

3.2 On-the-spot Survey

In the target district, there are many official and unofficial bicycle parking places scattered within the district. To know the "habitat" of bicycle parking places in the target district, on-the-spot surveys were first conducted. These surveys were conducted all other the district according to the schedule shown in Table 3 in order to identify common parking places for bicycles. For each survey, the places at which 3 or more bicycles were observed were counted. Private sites and the parking places which have locks on the gates are excluded from the data. Finally, the places which had been counted twice or more than that throughout the surveys are counted.

Table 3 Schedules of Conducted Surveys

No.	Date	Description
1	2013/07/21	Weekend/Morning
2	2013/07/22	Weekday/Evening
3	2013/07/27	Weekend/Afternoon
4	2013/07/29	Weekday/Night

Table 4 Vulnerability(V) and Resistance(R)-Related Items

V-A	Number of parked bicycles (Count average number of parked bicycles)
V-B	Accessibility from major arterial roads (Count minimum number of nodes to access to arterial roads)
V-C	Actual distance from major arterial roads (Measure actual distance to the nearest arterial roads)
V-D	Type of management (1. Care-taken, 2. Well-arranged but not care-taken, 3. Roughly parked)
V-E	Blindness from the nearest road (1. Blinded, 2. Not blinded) *1
V-F	Number of blinded directions (Count number of blinded directions) *2
V-G	Pedestrian traffic on the facing road (Survey number of pedestrians in the pictures taken for 4 directions)
R-A	Type of the parking place (1. Public road, 2. Residential bldg.., 3. Commercial / public bldg.., 4. Office building, 5. Designated parking lot)
R-B	Publicness of the place (1. Public, 2. Private)
R-C	Style of being shared (1. Open, 2. Limited, 3. Closed) *3
R-D	Visibility from surroundings on the place (1. Wall without windows, 2. Wall with windows, 3. Fences or plants, 4. Transparent wall, 5. Full-open)
R-E	Presence of critical observers (1. Not identified, 2. Lingering people, 3. Workers / Neighbors / residents, 4. Land / shop proprietor, 5. Custodian)
R-F	Mixedness of estimated destination (1. Single, 2. Multi, 3. Indiscriminate)
R-G	Dominant estimated destination (1. Unspecifiable, 2. Drop-by facilities, 3 Stay-in type facilities, 4. Residence or office, 5. Station) *4
R-H	Distance from the dominant estimated destination (1. In / under the building / place, 2. In front of the building / place, 3. Aside the building / place, 4. Across a road, 5. Around the building / place)

Table 2 Temporal Matrix of Bicycle Theft

Day \ Of Clock	0–1	1–2	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–10	10–11	11–12	12–13	13–14	14–15	15–16	16–17	17–18	18–19	19–20	20–21	21–22	22–23	23–24
Mon.	1	3	1	0	1	2	1	1	7	1	3	4	3	2	4	1	3	6	11	5	6	5	7	3
Tue.	2	1	0	0	0	1	0	1	3	4	4	1	3	3	1	4	4	3	4	3	4	6	3	6
Wed.	1	0	1	1	2	0	3	1	4	6	4	1	1	5	5	0	2	2	6	7	6	3	2	0
Thu.	1	1	0	0	1	0	1	3	5	2	2	4	1	5	1	1	5	6	2	10	6	6	4	2
Fri.	4	1	3	3	0	0	1	2	7	3	6	2	2	2	1	1	2	6	8	9	7	4	7	4
Sat.	2	1	1	0	2	2	1	1	3	3	3	3	7	4	2	7	3	8	13	3	7	6	1	4
Sun.	3	1	2	1	1	0	1	0	2	2	1	0	4	8	2	9	5	5	5	6	4	2	5	3

[Number of Bicycle Theft] (shading) = 0 - 2; = 3 - 4; = 5 - 6; = 7 - 8; = 9 or more

During the surveys, the followings are checked: 1) whether the place is a "difficult" place to commit a bicycle theft, 2) the check items about vulnerability shown in Table 4, 3) the check items about resistance shown in Table 4. In this research, the vulnerability-related items are extracted from Kashibayashi et al. (2008), and the resistance-related items are extracted from Sugino and Arima (2012).

3.3 General Results of On-the-spot Surveys

As the result of the surveys, the places which had been counted twice or more throughout all surveys are counted (in total 457) and plotted on a GIS map (Fig.5). Also, the data on all the bicycle thefts in the district is plotted on the GIS map by using an Address Matching Service. The density of the spots in which bicycle thefts were carried out was visualized by the Kernel density estimation method, and the visualized density map is overlapped on the map of bicycle parking places.

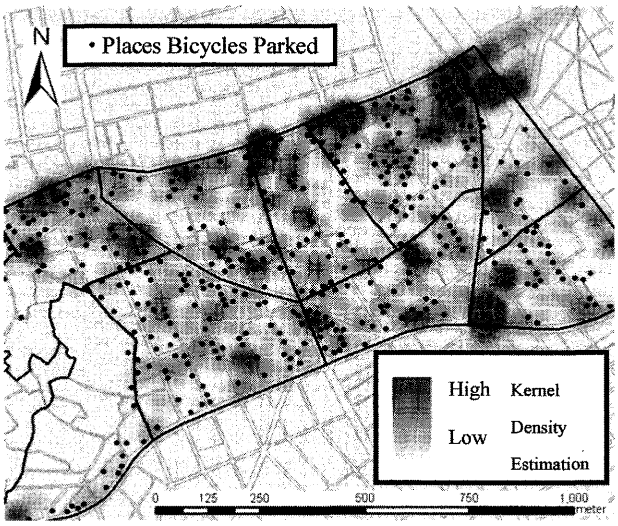


Fig. 5 Place Bicycles Parked and Density of Bicycle Theft

Interestingly, there are specific hot spots observed even though the distribution of bicycle parking places is not inclined over the map. On the contrary, there are some places which are not overlapped on the density distribution. This fact shows that there are not only "easy" places to commit bicycle theft but also "difficult" places at the same time in this district. In addition, this result implies that there are significant tendencies of bicycle theft convergence, and it is suggested to conduct further spatial analysis in order to see more about microscopic and macroscopic environment factors from psychological and physical point of views.

4. Spatial Analysis of Bicycle Parking Places

4.1 About Logistic Regression Analysis

In order to generate both sets of vulnerability and resistance-related indicators, univariate logistic regression analysis is utilized. The logistic regression analysis is a type of regression analysis used for predicting the outcome of a categorical dependent variable based on one or more predictor variables, and used in many disciplines, including the medical and social science fields. Here in this research, the bicycle parking places which have had two or more bicycle thefts are categorized as "hot spots," and it is used as the dependent variable for vulnerability, while the categorization of "difficult" place to commit a bicycle theft is utilized as the dependent variable for resistance. Also, each of vulnerability and resistance-related items in Table 4 is used as an independent variable in the analysis.

Generally, as the result of univariate logistic regression analysis, odds ratio is calculated. Odds ratio is generally defined in the formula shown below. It must be greater than 0, and there is positive correlation if it is greater than 1 while there is negative correlation if it is less than 1.

$$Exp(\beta) = \frac{p_1/(1-p_1)}{p_2/(1-p_2)}$$

$p1$: the probability of one event occurring
$p2$: the probability of another event occurring

4.2 Uni / Multi Variate Logistic Regression Analysis

As the result of the univariate logistic regression analysis, the odds ratio and level of significance for each item are shown in Table 5 and 6.

According to the result in Table 5, V-A, V-D1 and V-G have significant positive correlation with hot-spots of bicycle theft, and on the other hand, V-B, V-C, and V-F have significant negative correlation with hot-spots.

Therefore, if there are many bicycles parked and pedestrian traffic around the places, the places are tend to become hot spots. Besides, the distance from major arterial roads has negative correlation with the probability of becoming hot spots. Surprisingly, the condition of being "care-taken" has positive correlation with the probability of becoming hot spots, and this is because the places which are care-taken have usually many bicycles parked for a long time. Moreover, considering the result for the number of blinded directions, it is comparatively difficult to commit a bicycle theft at the parking places which are blinded from many directions.

Table 5 Result of Logistic Regression Analysis for Vulnerability

Items		Odds Ratio	Level of Significance	Items		Odds Ratio	Level of Significance
V-A		1.10	***	V-E	1	0.61	NS
V-B		0.66	***		2	1.63	NS
V-C		0.99	***	V-F		0.58	***
V-D	1	4.64	***	V-G		1.18	***
	2	0.75	NS	***: p < .001, **: p < .01, *: p < .05			
	3	0.74	NS				

Table 6 Result of Logistic Regression Analysis for Resistance

Items		Odds Ratio	Level of Significance	Items		Odds Ratio	Level of Significance
R-A	1	0.11	***	R-E	1	0.06	***
	2	1.66	NS		2	2.62	*
	3	4.34	***		3	1.06	NS
	4	1.40	NS		4	5.76	***
	5	1.20	NS		5	9.92	***
R-B	1	3.08	***	R-F	1	0.58	NS
	2	0.32	***		2	2.29	**
R-C	1	2.94	***		3	0.81	NS
	2	2.41	**	R-G	1	0.86	NS
	3	0.16	***		2	6.93	**
R-D	1	0.17	***		3	1.31	NS
	2	0.91	NS		4	0.22	***
	3	0.35	NS		5	13.13	NS
	4	6.94	***	R-H	1	0.05	***
	5	2.63	*		2	5.54	***
***: p < .001, **: p < .01, *: p < .05					3	0.79	NS
					4	0.00	NS
					5	1.01	NS

Also, Table 6 shows the result of logistic regression analysis for resistance. According to the results of analysis, R-A3, R-B1, R-C1, R-C2, R-D4, R-D5, R-E2, R-E4, R-E5, R-F2, R-G2, and R-H2 have significant positive correlation with difficulties to commit a bicycle theft, while R-A1, R-B2, R-C3, R-D1, R-E1, R-G4, and R-H1 have significant negative correlation.

The result indicates the conditions which make parking places "difficult" to commit a crime. For example, a parking place attached with commercial or public building, a place which is public and shared openly or limitedly, or a place whose destination is a drop-by facility which is located in front of the place.

Based on the result of both uni-variate logistic regression analyses, the items which have significant correlation with each vulnerability and resistance are selected. Then, utilizing the selected variables, multi-variate logistic regression analyses with stepwise procedure were carried out for the sets of indicators to generate efficient regression models. Table 7 and 8 show the final selected indicators for vulnerability and resistance respectively.

Table 7 Vulnerable Indicators and Each Coefficient Values

	Coefficient	Indicators
Intercept	-0.845651	
V-a	-0.061025	Number of parked bicycles (Count average number of parked bicycles)
V-b	0.002874	Actual distance from major arterial roads (Measure actual distance to the nearest arterial roads)
V-c	1.596787	Type of management (Care-taken or not)
V-d	-1.022104	Number of blinded directions (Count number of blinded directions)
V-e	0.085628	Pedestrian traffic on the facing road (Survey number of pedestrians in the pictures taken for 4 directions)

Table 8 Resistance Indicators and Each Coefficient Values

	Coefficient	Indicators
Intercept	-2.7003	
R-a	1.2987	Publicness of the place (Public or not)
R-b	1.9135	Visibility from surroundings on the place (Transparent wall or not)
R-c	0.7881	Visibility from surroundings on the place (Full-open or not)
R-d	-2.4776	Presence of critical observers (Not identified or not)
R-e	2.3474	Presence of critical observers (Land / shop proprietor / Custodian or not)
R-f	0.9025	Dominant estimated destination (Drop-by facilities or not)
R-g	1.1806	Dominant estimated destination (Residence or office)
R-h	-2.0499	Distance from the dominant estimated destination (In / under the building / place or not)

4.3 Actual Condition of Bicycle Thefts and the Scores of Vulnerability and Resistance

Utilizing the multi-variate logistic regression models, vulnerability scores and resistance scores for each bicycle parking places are calculated. The scores are indicated within the range of 0 to 1 ($0 < \text{score} < 1$).

Then, in order to see the relationship between actual condition of bicycle theft occurence and the scores of vulnerability and resistance, a distribution matrix (5×5) was produced (Fig. 6). The vertical axis and horizontal axis indicate the vulnerability score and resistance score respectively, and each mesh indicates the average number and frequency of bicycle theft occurrence for plotted bicycle parking places within the territory of each.

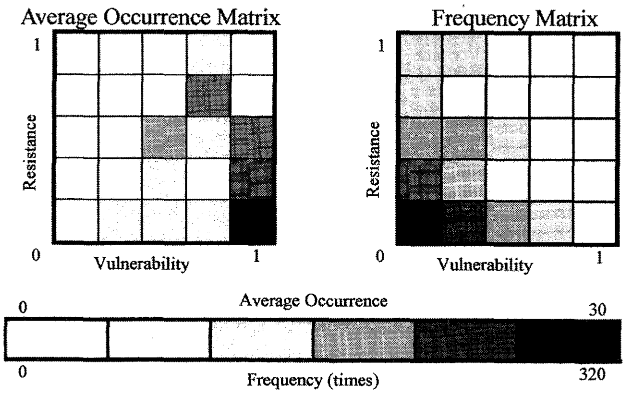


Fig. 6 Distributions for Average and Frequency of Bicycle Theft

Accordingly, the following tendencies were implied: 1) there is a huge possibility for bicycle parking places to become a hot spot when they have strong vulnerability and week resistance, 2) the possibility to become a hot spot can be decreased if they have strong resistance even their vulnerability score is strong, 3) the possibility to become a hot spot can be increased if they have equality of both factors, and especially when both of them are moderately strong, and 4) there are many bicycle parking places whose vulnerability and resistance are both low and have held small amount of bicycle thefts.

5. Defensibility and Each Possible Improvement

5.1 Antagonism Line and Kurtosis Line

Based on the result of the distribution matrix, it was clarified that the trend of bicycle theft occurrence cannot be defined by a simple regression model. Therefore, we turned our attention to the tendencies in the matrix discussed in 4.3, and generated a calculation model for defensibility as focusing on the antagonism line and kurtosis line (Fig. 7).

In the matrix, the antagonism line indicates equality of resistance and vulnerability. As one of the criteria, if the plot of resistance and vulnerability for a bicycle parking place is placed near this line, there is high possibility to become a hotspot.

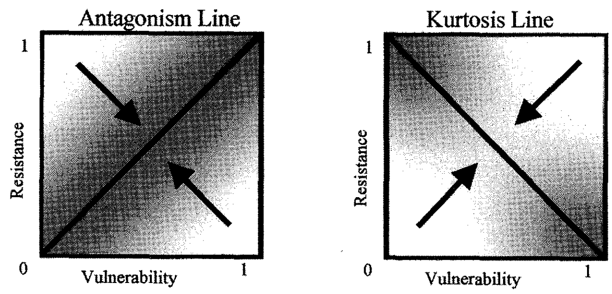


Fig. 7 Antagonism Line and Kurtosis Line

Also, the kurtosis line indicates how keen the dominant factor (resistance or vulnerability) is. If the calculated scores are plotted near this line, the dominant factor (resistance or vulnerability) is keen. Conversely, if a plot is far from this line, the effect of both resistance and vulnerability will be blurred.

5.2 Calculation Model for Defensibility

In Fig. 7, the antagonism line and kurtosis line can be drawn as equations, y=x and y=-x+1, respectively. Utilizing the antagonism line as a tipping line, the defensibility of a plotted point (x_0, y_0) can be indicated by the equation below:

$$\text{Defensibility} = \frac{y_0 - x_0}{\sqrt{2}}$$

Basically, the parking place is defensible if the defensibility score is positive, and it is vulnerable if the score is negative. However, it is also needed to check the followings utilizing the antagonism line and kurtosis line:

1) Antagonism Check: If the absolute value of defensibility is close to 0 (which means the plot is close to the antagonism line), it is possible for the place to become a hotspot even the defensibility score is positive.

$$\text{Antagonism Value} = |\text{Defensibility}|$$

2) Kurtosis Check: The kurtosis value can be calculated with the equation below. If the value is close to 0, the defensibility will not be blurred, but the blurredness can increase in response to the kurtosis value.

$$\text{Kurtosis Value} = \frac{|y_0 + x_0 - 1|}{\sqrt{2}}$$

5.3 Categorization and Appropriate Improvement for Each

According to calculation of each score explained in 5.2, it is possible to detect the latent vulnerable spots even if they have not had any bicycle thefts yet. Fig. 8 shows the contour map of average number of bicycle thefts, and bicycle parking places can be categorized into 4:

a) Defensible place: Resistance is dominant, and plots are far from the antagonism line.

b) Vulnerable place: Vulnerability is dominant, and plots are far from the antagonism line.

c1) Unstable place 1: Strong resistance and vulnerability compete with each other, and plots are near to the antagonism line (Frequency = low).

c2) Unstable place 2: Weak resistance and vulnerability compete with each other, and a number of plots are placed near to the antagonism line (Frequency = high).

Table 9 shows the examples of bicycle parking places categorized in b) and c1) which have high probability to become hot spots but have not had any bicycle thefts yet.

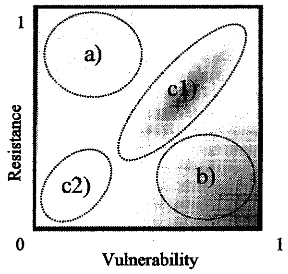
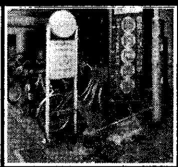
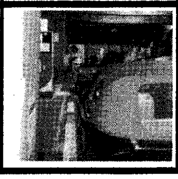


Fig. 8 Contour Map and Categorization of Bicycle Parking Places

Table 9 Examples of Places Categorized in Each Group

a)		Lot No.	174
		Resistance	0.92
		Vulnerability	0.11
		Defensibility	0.57
		Antagonism Check	0.57 (Strongly stable)
		Kurtosis Check	0.02 (not blurred)
b)		Lot No.	420
		Resistance	0.04
		Vulnerability	0.64
		Defensibility	-0.42
		Antagonism Check	0.42 (Moderately stable)
		Kurtosis Check	0.23 (Moderately blurred)
c1)		Lot No.	126
		Resistance	0.41
		Vulnerability	0.57
		Defensibility	-0.11
		Antagonism Check	0.11 (Strongly Unstable)
		Kurtosis Check	0.01 (not blurred)
c2)		Lot No.	122
		Resistance	0.00
		Vulnerability	0.06
		Defensibility	-0.04
		Antagonism Check	0.04 (Significantly unstable)
		Kurtosis Check	0.66 (Strongly blurred)

The first example has an ideal one-sided plot indicates strong resistance and weak vulnerability. Since the plot was placed away from the antagonism line, this defensible place has small possibility to become a hotspot. Also, according to the result of the kurtosis check, the defensibility is not blurred at all. For this kind of the place, no special improvement is required, but it is needed to check periodically if the surrounding environment has changed or not and attest the defensibility of the place has been kept appropriately.

For the next one-sided plot example indicates strong vulnerability and weak resistance. Therefore, it can be said that the place is a latent vulnerable spot against bicycle theft. To improve the weak resistance, it is better to make some public custodians come around here in order to make the presence of critical observer there.

Also, for the third example, the plot is almost on the antagonism line. It has moderate resistance but vulnerability at the same time. Therefore, the place has not had any bicycle theft but it is possible to have some in the future. Since there is no wall against a road, a fence or transparent wall can make the place look private and increase defensibility.

Finally, the forth example categorized in c2) has both weak vulnerability and resistance. Naturally, the value of defensibility is close to 0, and it is significantly unstable according to the result of the antagonism check. Also, the kurtosis value is very high and the result should be considered strongly blurred. However, that result also means that this kind of places have possibility to become defensible places by improving the factors related to resistance. It is not urgent for urban planners to make environmental improvement for the places categorized in c2), but needed to check places often and catch an indication to become vulnerable places.

6. Conclusion

In the beginning of this study, the temporal vulnerabilities against bicycle theft in the targeted district are explained. Then, throughout the on-the-spot survey, both vulnerability-related and resistance-related spatial features were checked, and the factors which have significant impact for each vulnerability and resistance. Additionally, utilizing multi-variant logistic regression analysis, indicators and coefficient values were clarified to calculate scores for each vulnerability and resistance. Finally, the sequential results of this study have discovered "defensibility" of bicycle parking places against bicycle theft with equation models based on vulnerability and resistance. Also, a scatter diagram clarifies the antagonism between vulnerability and resistance, and is able to detect the vulnerable spots.

The models can indicate where and what is needed to be improved in order to reduce the number of bicycle theft. Utilizing the equation, it is possible to find appropriate improvements on specific types of vulnerable bicycle parking places categorized based on the balance of two factors.

In this study, it was succeeded to describe vulnerability and resistance of bicycle parking places and discuss more accurate and practical defensibility. However, the evaluation items and method in this study were developed based on the results of previous studies, and therefore, it is possible for the further studies to evaluate other environmental factors, such as occluded area and occlusion angle of the wall surrounding the parking places, since surveillance should be considered not only horizontally but also vertically in urban areas.

Moreover, microscopic on-the-spot survey on spatial factors was conducted in this study regarding the fact that there are specific hot spots observed even though the distribution of bicycle parking places is not inclined over the map. For the further studies following as an extension of this study, it is suggested to conduct the condition and ambience of bicycle parking places to supplement empirical knowledge for bicycle theft prevention with the results derived from this study.

Finally, since these results are specifically derived for the targeted district based on their current physical condition, and so the versatility of the results can be small, and hence it is needed to conduct another research if the vulnerability and resistance are needed to be clarified for another place. Furthermore, if these kinds of researches are going to be accumulated like medical clinical researches, it will be also possible to find out some versatile outcomes in the future. Also, attesting the models in other districts is still a task needed in the future.

Note

*1: This evaluation item is about "blindness," and so not only walls but also huge obstacles, blinding fences, or corners shaped like "L" are regarded as physical environmental elements possible to create blindness.

*2: This item does not indicate simple walls or fences to make blinded directions, but it is about the directions to which intended bicycle-thieves should not pay attention. If the number of blinded directions is small, intended thieves need to pay attention to many directions and it increases the psychological costs they need to consume.

*3: Bicycle parking places are shared in various ways. For example, public roads are considered open-shared type, and parking lots located in front of restaurants or cafes are considered limited since they are not strictly exclusive. There are some strictly exclusive parking lots such as the one for residents of an apartment located in its ground floor, and these places are considered closed type.

*4: The dominant estimated destination can sometimes be unspecifiable in different two ways. First, especially in an urban center, bicycle parking places are shared with many destinations, and it is hard to identify one specific destination where bicycle owners went. Second, people sometimes park their bicycles on public roads for some reasons, and it is hard to estimate a dominant destination if the places are in the middle of a road and not surrounded by any buildings.

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（受理：平成25年11月14日）