Study on the Incidence of Opportunity Crime on Residential Streets Considering Traffic Volume and Visible Range

Abstract

As a basic step, in this study we propose a model to describe the snatch incident on residential streets. This model is based on one of the methodologies of social science and the Crime Prevention Through Environmental Design's concept. The objective variable is the feasibility of snatch and explanatory variables are physical factors concerning road network design and traffic regulation, like traffic volume and visible range on streets.

As the result of the application to actual situations, the model provided reasonable predictions for distribution of point of incidence in a street section. It is possible to examine the influence that road network design and traffic regulation have on snatch by extending this model to road network.

Author

Chiaki MATSUNAGA
Assistant Professor, Department of Urban & Environmental Engineering, Faculty of Engineering, Kyushu University (744 Motooka, Nishi-ku, Fukuoka, 819-0395, Japan)
E-mail: matunaga@doc.kyushu-u.ac.jp

Daiki OKUDA
Transport Information Technology Division, Railway Technical Research Institute (2-8-38 Hikari-cho, Kokubunji-shi, Tokyo, 185-8540, Japan)

Kenichi TERAMACHI
Associate Professor, Ph.D. (Eng.), Department of Civil and Architectural Engineering, Faculty of Engineering, Kyushu Institute of Technology (1-1 Sensui-cho, Tobata-ku, Kitakyushu-shi, Fukuoka, 804-8550, Japan)

Tomonori SUMI
Professor, Ph.D. (Eng.), Department of Urban & Environmental Engineering, Faculty of Engineering, Kyushu University (744 Motooka, Nishi-ku, Fukuoka, 819-0395, Japan)

Key Words: Crime Prevention Through Environmental Design (CPTED), Street network design, Opportunity crime, Traffic volume, Visible range

Introduction

Background

In Japan, the number of crimes as defined in criminal law recorded in 2002 was the highest since World War □. Although this number declined over the next years, it remains at about 1.5 times the lowest level, which occurred around 1965. "Opportunity Crime" such as robbery and snatch on the streets shows notable growth after 1996 (National Police Agency, 2009). Since the crime-arrest ratio has not improved significantly, other new measures for crime prevention are necessary in addition to ex-post measures such as strengthening of correction and penalty.

With this background, the theory and method called "Crime Prevention Through Environmental Design (CPTED)" is attracting a lot of attention especially in the field of City Planning and Community Planning. CPTED is one of the theories and methods for crime prevention developed in the USA in the 1960's when increasing crime and declining security were serious social problems, and the CPTED theory and method has also been drawing attention in Japan in recent years. CPTED is based on the concept that "the proper design and effective use of the built environment can lead to a reduction in the fear and incidence of crime, and an improvement in the quality of life." (National Crime Prevention Council United States, 1997) CPTED is based on three principles that provide systemic change and support problem-solving approaches to crime: natural access control, natural surveillance, and territorial reinforcement (National Crime Prevention Council United States, 1997).

Most methods based on CPTED focus on development and layout of infrastructure, or reinforcement of the community. On the other hand, crimes, particularly most of opportunity crimes that can be controlled efficiently by CPTED are committed on the streets. Almost all criminals use the streets to access and escape from the crime scene. However, street network design and traffic regulations are primarily oriented toward efficient traffic management, traffic safety, etc. Therefore, the relation between traffic and crime has received little attention. Because street network design and traffic regulations are tools and fundamental technologies of city planning that determine the shape of the city, we can't discuss the urban safety and security outside the context of crime prevention based on transportation planning.

Literature review

A large amount of research has been carried out on crime prevention and CPTED in urban space. Saito (1991) statistically analyzed and compared urban spatial factors that influenced the incidence of and anxiety for crime in apartment areas. Uesugi et al. (1999) analyzed the influence of anxiety over crime on residents' choice of community parks. Himura and Koide (1999) carried out researched into factors affecting arson attacks such as the location and type of site, ignition device, etc. Ito et al. (1999) categorized the arson attacks with quantification theory class □, and analyzed the relation between the pattern of arson attacks and spatial characteristics of the site using AIC calculation. Chinoi et al. (1999, 2004) analyzed the results of a survey questionnaire on the scene of crimes and anxiety about crime in residential estates and parks, and studied local citizens' crime prevention activities. Hino (2006) carried out the research into the relationship between land-use and incidence of burglaries comparing the difference in the number of incidences between observation and prediction calculated on the number of households. Nagaie and Hokao (2006) used the multiple linear regression analysis to study on the interrelation between anxiety for crime and spatial components. Onogi et al. (2007) investigated the status of security equipments like security cameras and community gates and the background of estate development in community towns. Although these studies were focused on the facility placement and land-use, there was little consideration of the factors concerning transportation.

Studies on the relation between transportation and crime are listed below. Himura et al. (2003) carried out research into the qualitative analysis of the space leading to anxiety for crime and the space of incidences of snatch in residential districts around railroad stations. Noda et al. (2003) treated statistically the relation between pedestrians' route choice and incidence of crime or their anxiety. Gokita and Ohsawa (2002) proposed a model quantifying the safety of streets considering traffic volume and density of street lamps. Nagaie et al. (2007) calculated the special index of surveillance and territorial performance in residential districts, and analyzed their influence on anxiety for crime considering Space Syntax Theory. These studies pointed out the relationship between traffic phenomenon and crime incidence. However, they did not discuss the possibility of anticrime measures using street network design and traffic regulations.

Based on this background, the purpose of this study is to discuss the effect of street network design and traffic regulations on crime. As a first step, we treat street crime in residential districts, and propose a model that describes the mechanism of crime incidence considering the influence of traffic volume and visible range.

Trends of street crimes and hypothesis from the viewpoint of CPTED

Trend analysis of street crimes

As a first step in this study, we analyzed the tendency and characteristics of street crimes. The data employed is from "Fukkei Anshin Mail (Crime information mail)" distributed by Fukuoka Prefectural Police and covers the time period from July 2007 to June 2008. In this mail, the information about crimes incidence including attempts, is presented: date, place, criminals and victims' attributes such as sex, age, travel mode, extent of damage, etc. This information is based on notices to police. Their accuracy and reliability are therefore questionable. However, we use this information because the street crimes include also minor offenses and attempted crimes not reported by official statistical data. During the period investigated, 1915 cases were reported by Crime information mail, and we analyzed 1158 crimes committed on the streets including walking paths, underground passages, farm roads, etc. and around the door ways of roadside facilities like schools, apartments, etc.

Fig. 1 shows the breakdown of crime incidence. The largest number of incidents was snatch with 345 cases (30%), molestation with 218 cases (21%), flash with 218 cases (19%), suspicious greeting with 178 cases (15%), tagging with 88 cases (8%), suspicious and violent behaviors with 72 cases (6%) and others with 11 cases (1%). Fig. 2 shows the attributes of the victims. All or almost all the victims of each crime type are females. Especially, almost all victims of property offences and sexual crimes like snatch, molestation, flash, etc. are female high-school students and adult females. Victims of suspicious greetings and suspicious and violent behaviors are by comparison younger. On the other hand, almost all criminals were identified their sex as male. The time distribution of crime incidence is shown at Fig. 3. These crimes have a propensity to be committed mostly in the morning and

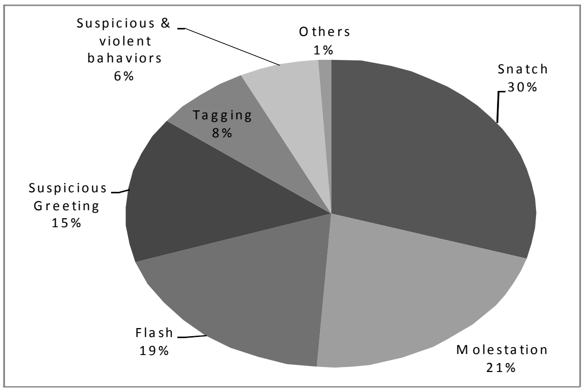

Fig. 1 Breakdown of crime incidence by type

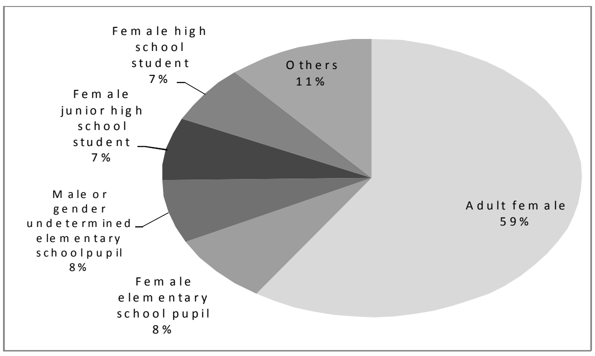

Fig. 2 Attributes of victims

from evening into the night. We think that the reason for this propensity is that the targets are different depending on crime type, and the presence or absence of ideal targets is also different depending on time.

Hypothesis of street crime from the viewpoint of CPTED

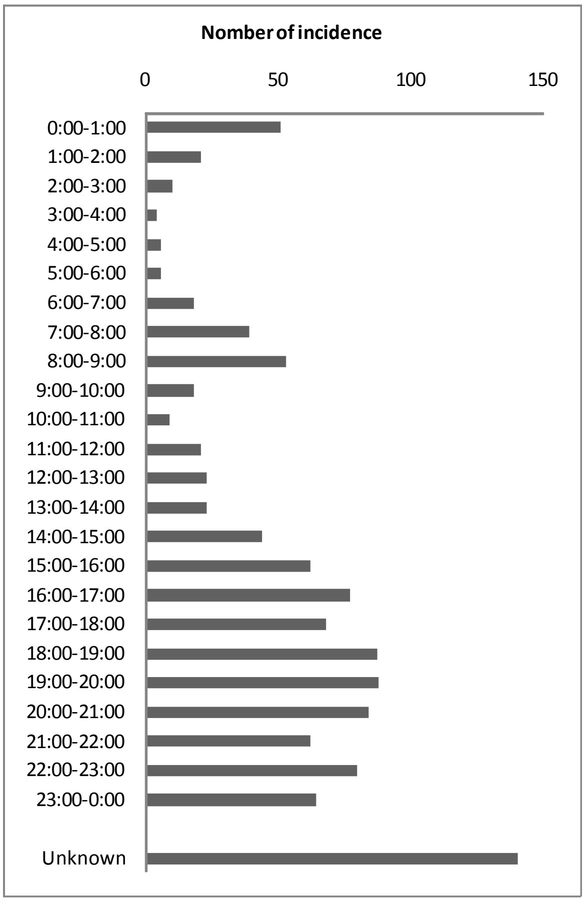

Fig. 3 Time distribution of crime incidence (1158cases)

The analysis of chapter 2 suggests that almost all street crimes belong to "the opportunity crime". The opportunity crime depends on the opportunity to encounter targets and the situation at the crime scene (Cohen and Felson, 1979). It means that efficient control of crime incidence involves using CPTED. Considering this, we could say that the environmental factors around the scenes of crime influence criminal behavior. Therefore, if the factors are different for each scene, the crime incidences might be different depending on the crime scene. And the factors' influencing criminal activity also might be different.

As to the factors that influence street crimes, we can consider socioeconomic factors like the economic situation and social condition of the community, and physical factors like traffic volume, street network and facilities along the streets. In this study, we treat only physical factors which could be controlled by CPTED. Especially, we treat the factors concerning surveillance such as traffic volume of pedestrians and vehicles that can easily be controlled by street network design and traffic regulations.

Thus, we attempt to make a model whose explanatory variables are physical factors concerning street environment and whose objective variable is the feasibility of street crimes. Although the ultimate foal of this study is to apply this model to whole street networks, we take one block as the basic unit. It would be possible to describe the relationship between crime incidence and physical factors on street networks with the proposed simulation model extended two-dimensionally (Sueshige et al., 2008).

Modeling of criminal behavior

Intended crime and its characteristics

Among the opportunity crimes, this study is aimed at snatch executed in residential districts that consist mainly of single family houses. Some features of snatch are reported as follows: 1) almost of them are committed on the streets, 2) nearly all the victims are females, 3) about a half of the cases recorded are committed within a radius of 500m of the victim's house, etc (Website of Hyogo Prefectural Police Department, 2011). Some features of the criminals' behaviors, have been also reported by investigators (Website of Hyogo Prefectural Police Department, 2011/Website of Wako Bosai Co., Ltd., 2011): 1) criminals choose the least risky way not to be blocked, 2) they target a defenseless female where there is no witnesses around, 3) they approach the target from behind using vehicles like a motorcycle or bicycle, 4) about 80% of criminals turn left at the corner to escape from the criminal scene, etc.

We can see from the above that the incidence of snatch and the criminals' behaviors are lawfully explicable. That is why we study the snatch along with additional reasons as follows: 1) the time of incidence can be identified, 2) snatch is influenced significantly by traffic volume and street condition because it is committed on the street. And we also limit our research to cases in residential districts to eliminate influences from uncertain factors and socio-economic factors mentioned before.

Methodology of modeling

Our proposed model is based on one of the methodologies of social science. This theory consists of "Methodological Individualism", "Logic of Situation (Assumption of Optimization)" and "Zero Method (Deviation from Optimum)". "Methodological Individualism" is the axiom that the task of social theory is to construct and to analyze our sociological models carefully in descriptive or nominalist terms, that is to say, in terms of individuals, of their attitudes, expectations, relations, etc (Popper, 2002). "Logic of Situation (Assumption of Optimization)" is the method of describing provisionally, and a priori, the human behavior, taking into account the propensity of people to behave depending on the situation faced by them at different times, and that they regard their behaviors as rational when their behaviors follow "the logic of situation" (Kojima, 1978). "Zero method" is the method of constructing a model on the assumption of complete rationality (and perhaps also on the assumption of the possession of complete information) on the part of all the individuals concerned, and of estimating the deviation of the actual behavior of people from the model behavior, using the latter as a kind of zero co-ordinate (Popper, 2002).

In cases where we can't observe the crime, as in snatch, it is necessary to formulate some hypotheses about how it happens. As noted before, criminal behavior depends on some laws. When these laws are consistent with an individual's rationality, the model can be made by forming some hypotheses about criminal behaviors in order to satisfy the methodology of social science.

Criminals and witness' behaviors and peccability of crime

We take one section of street shown in Fig. 4 as the situation to apply the model. The arbitrary point x in the section represents the crime incidence point, and the numerical value of x represents the distance from this point to the corner in the direction of motion of criminal. As an assumption, a criminal approaches the target from behind, executes a crime at the point x and escapes. What a criminal regards as most

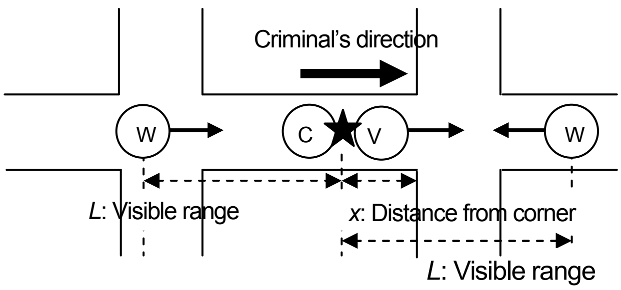

Fig. 4 Illustration of Snatch incidence

important when he takes these series of behaviors is that no witnesses appear from the beginning to the end of the crime. Therefore, the suitable conditions for criminals to execute crimes are "there is no witnesses at the beginning of the crime" and "no witnesses appear during execution of the crime".

Thus, if these conditions are independent of each other and they are described by probabilities, the probability $P'(x)$ that a criminal has suitable conditions to execute a crime at point x is given by the product of the probability $P_s(L)$, the probability of no witnesses at the beginning of the crime, and the probability $P_c(x)$, the probability of no witnesses from the start to the conclusion of the crime. The total probability $P'(x)$ is shown at Eq. (1).

$$P'(x) = P_s(L) \times P_c(x) \tag{1}$$

Criminals consider whether these two conditions are enough, and they don't commit a crime until the value of $P'(x)$ in Eq. (1) exceeds a certain reference value. This value could be different for each criminal. The reference value is described as the threshold value P_t, and its probability density function (PDF) is given with $\Phi_{Pt}(P)$ that describes criminals' individual differences. Furthermore, the uncertain factors make for a difference between execution possibility and substantial execution, so we introduce an adjustment variable α into the possibility $P'(x)$. The feasibility of snatch at the point x is given at Eq. (2) considering function $\Phi_{Pt}(P)$ and variable α.

$$P(x) = \alpha \times P'(x) \times \int_{P_t}^{1} \Phi_{P_t}(P)\,dP \tag{2}$$

Since $P(x)$ describes the feasibility of snatch at an arbitrary point x in a section of street, the distribution of feasibility over an entire section of street is described by the distribution of $P(x)$.

The contents of Eq. (1) and Eq. (2) are explained in detail at the section 3.3.1 and 3.3.2 assuming criminals and witnesses behaviors.

Probability that witness doesn't appear at the beginning of crime

If someone happens on an incident, he could witness the crime. The existence of witnesses depends on surveillance from roadside facilities and traffic volume of pedestrians and vehicles around the crime scene. In this study, we consider only traffic volume because the surveillance from roadside facilities is regarded as homogeneous in residential districts which consist mainly of single family houses.

We assume that traffic around a crime scene appears in random order, and the PDF of the time interval of the traffic obeys an exponential distribution. Since traffic is different depending on its mode such as pedestrian or vehicle and its direction, we discriminate traffic volume by mode and direction to consider the difference in influence by them and the patterns of street traffic such as one-way or not. The witness's velocity is given with V_i where the suffix describes their mode and direction with respect to the criminal's direction, and the time interval is also given with t_i. Thus, the PDF of witnesses' time interval $\Phi_i(t_i)$ is given at Eq. (3).

$$\Phi_i(t_i) = \lambda_i \exp(-\lambda_i \times t_i) \tag{3}$$

Suffix i is assigned values from 1 to 4, and describes the type of witness and their direction: 1 is a pedestrian moving in the same direction as the criminal, 2 is a vehicle in the same direction as the criminal, 3 is a pedestrian in the opposite direction as the criminal and 4 is a vehicle in the opposite direction as the criminal. λ_i describes the average frequency of occurrence per hour of witnesses (i : type of witness), and they are given for each traffic volume.

A criminal recognizes pedestrians and vehicles which appear within the time interval given by Eq. (3) as witnesses, and feels a menace from them only if the distance between criminal and witness is shorter than a reference value. This reference value is described as the visible range, and it varies depending on season, hour and illumination. We consider only the visible range in front of the criminal's direction because the influence of witnesses within the visible range in front of the criminal is dominant for the criminal, and pedestrians and vehicles behind the criminal influence the criminal much less than the victim.

Thus, when, the distance between witnesses is longer than the visible range, there are no witnesses within the visible range at the beginning of the crime. As noted before, the PDF of witnesses' time interval $\Phi_i(t_i)$ is described by an exponential distribution, witness's velocity is V_i and visible range is described by L. The probability $p_{si}(L, t_i)$ that there are no witnesses of type i is given by Eq. (4). Eq. (4) is describes the probability when the witnesses' time interval t_i exceeds L/V_i as given by Eq. (3).

$$\begin{aligned} p_{si}(L, t_i) &= \lambda_i \int_{t_i}^{\infty} \exp(-\lambda_i \times t)\,dt \\ &= \lambda_i \int_{\frac{L}{V_i}}^{\infty} \exp(-\lambda_i \times t)\,dt \end{aligned} \tag{4}$$

λ_i: average frequency of occurrence par hour of witness (i : type of witness)

The probability p_{si} (L, t_i) varies depending on mode and direction of witness. When all modes and directions are considered, their traffic volumes are independent of each other. Therefore, the probability $P_s(L)$ that all types of witness are not within the visible range is given at Eq. (5).

$$P_s(L) = \prod_{i=1}^{4} p_{si}(L, t_i) \tag{5}$$

Probability that witness doesn't appear during the crime

Snatch criminals escape as soon as they contact the target and execute the crime. According to the reports (Website of Hyogo Prefectural Police Department, 2011), about 80% of snatch criminals turn left at a corner they encounter on their escape route and they have a propensity to avoid being recognized by their victim, so we can assume that most criminals turn left at the nearest corner in their escape. Therefore, the time required to accomplish the snatch corresponds to the time required to snatch money and/or goods from the target at the point x and turn the corner. The situation is illustrated in Fig. 4.

As depicted in Fig. 4, we assume that the criminal executes the crime at an arbitrary point x which is located a distance x (m) from the corner. We assume also that the criminal takes a sequence of actions consisting of approaching the target from behind using a motorcycle or bicycle, snatching the money and/or goods and escaping at constant velocity. However, as the criminal approaches the corner, his motion must become slower in order to turn the corner. We separate the criminal's escape route to a linear section and a curved section to consider the difference of criminal's motions in each section. The straight-line distance and the travel distance for each section are described by x_{str}, x_{cir}, L_{str} and L_{cir}, respectively. Crime point x and escape distance L_{esc} are given at Eq. (6).

$$\begin{aligned} x &= x_{str} + x_{cir} \\ L_{esc} &= L_{str} + L_{cir} \end{aligned} \tag{6}$$

x_{str}: linear sectional distance
x_{cir}: curved sectional distance
L_{str}: linear travel distance
L_{cir}: curved travel distance

While the velocity in the linear section is taken as V_{str}=const, we assume that the criminal travels in a circular arc with curvature radius r and maximum allowable acceleration α. Therefore, the velocity in the curved section V_{cir} is given at Eq. (7) and its locus is shown in Fig. 5.

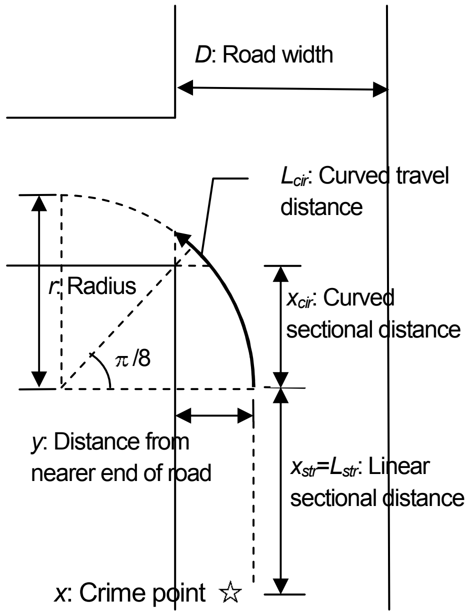

Fig. 5 Criminal's travel locus in curved section

$$V_{cir} = \sqrt{ar} \tag{7}$$

Since we assume that the target walks along the edge of the road, the distance of the criminal from the nearer end of the road y is assumed one-half of the street width D at maximum. The relationships among curved travel distance L_{cir}, curvature radius r and curved section distance x_{cir} is given at Eq. (8).

$$\begin{aligned} & L_{cir} \approx \frac{\pi r}{4} \\ & r\sin\frac{\pi}{8} \approx x_{cir} = r - y \\ & \therefore x_{cir} \approx \frac{r}{\sqrt{2}},\ y \approx r\left(1-\frac{1}{\sqrt{2}}\right) \\ & \frac{D}{2} \geq y \end{aligned} \tag{8}$$

The required times in the linear section and curved section are t_{str} and t_{cir}, respectively. Then, the duration of the crime is given in Eq. (9) as the sum of t_{str} and t_{cir}, using the relation between distance and velocity.

$$t_{esc} = t_{str} + t_{cir} = \frac{L_{str}}{V_{str}} + \frac{L_{cir}}{V_{cir}} \tag{9}$$

When a witness doesn't appear within this time interval, t_{esc}, the interval time of pedestrians and vehicles must be longer than t_{esc}. The probability when the time intervals of all modes and directions of witness are longer than t_{esc} at the point x is shown at Eq. (10) considering Eq. (3).

$$P_c'(x) = \prod_{i=1}^{4} \int_{t_{esc}}^{\infty} \Phi_i(t_i)\, dt_i = \prod_{i=1}^{4} \lambda_i \int_{t_{esc}}^{\infty} \exp(-\lambda_i \times t_i)\, dt_i \quad (10)$$

t_{esc} : duration of crime

t_i : time interval of witness (i: type of witness)

λ_i : average frequency of occurrence per hour of witness (i : type of witness)

$\Phi_1(t_1)$: PDF when pedestrian in the same direction as criminal enters within visible range

$\Phi_2(t_3)$: PDF when vehicle in the same direction as criminal enters within visible range

$\Phi_3(t_3)$: PDF when pedestrian in the opposite direction of criminal enters visible range

$\Phi_4(t_4)$: PDF when vehicle in the opposite direction of criminal enters visible range

According to Eq. (9), the duration of the crime becomes shorter as the crime scene moves closer to the corner, and the value of $P_c'(x)$ in Eq. (10) becomes smaller as the values of x become smaller. The model predicts that success rate of snatch crime rises as the crime scene approaches the corner. Although, when the crime scene is near the corner, the criminal has to decelerate to make the rotational motion to turn the corner just after the crime and the effective success rate degrades more than expected because the criminal doesn't leave enough distance to escape so as not to be recognized by his victim. Thus, in addition to the traffic volume of witness, we take another factor as a parameter. This parameter explains the criminal's risk depending on the distance of the crime scene from the corner, and it is taken as $\rho(x)$ because its volume varies with the point x. Eq. (10) is reworked into Eq. (11) with parameter $\rho(x)$.

$$P_c(x) = \rho(x) P_c'(x), \quad 0 < \rho(x) \leq 1 \quad (11)$$

Here we explain how we estimate the parameter $\rho(x)$. When the crime scene is near the corner, the criminal turns the corner immediately and the escape route is described by rotary motion. In this situation, the duration of the crime t_{esc} is equal to t_{cir} and it is given by velocity and distance as in Eq. (9). The velocity of the criminal V_{cir} is given in Eq. (7). Concerning Eq. (7), the acceleration to safely drive the curved section is determined by road conditions and the criminal's psychology. In this study, we assume the acceleration α as $0.3g$ (g is gravitational acceleration) considering that the friction coefficient of the road is normally 0.4-0.8 so the maximum centrifugal acceleration is taken as 0.3g when we calculate the Non-passing sight distance (Uchida and Onitsuka, 1994). Thus, Eq. (7) is reworked as follows.

$$V_{cir} = \sqrt{0.3gr} \quad (12)$$

We consider the range of x to be 0<x□7.5m, because the beginning point to turn the corner is 7.2m as determined by Eq. (8) for a maximum road width of 6.0m. We assume the maximum road width as 6.0m because this model is intended for streets in residential districts. The duration of the crime, t_{esc}, and the average of V_{cir} are calculated using Eqs. (8) and (12), and they are shown in Table. 1. We assume that there is a time delay between criminal act and victim reaction because almost all victims are female pedestrians and they begin to chase the criminal only after becoming aware of being a victim of snatch. Table. 1 shows that the criminal will not be able to escape if point x is less than 3.0m where the average velocity of the criminal is less than about 3.5km/h, even if we consider the time delay between criminal and victim reaction. We take the parameter $\rho(x)$ as 0 when the point x is less than 3.0m. On the other hand, even if the point x is more than 3.0m, it is possible that criminals can be recognized by their victims until the criminal moves away enough so as not to be recognized. Therefore, it is likely that the criminal tends to control his behavior before the beginning of turning the curve. Thus, when the point x is more than 3.0m, we take parameter $\rho(x)$ as the cumulative distribution function (CDF) of the standard normal distribution.

Table 1 Duration of crime t_{esc} and the average of V_{cir}

Point x [m]	Radius r [m]	Duration of crime t_{esc} [s]	Average velocity in curved section V_{cir} [m/s]
0.5	0.71	0.77	1.45
1.0	1.14	1.09	1.64
1.5	2.12	1.33	2.50
2.0	2.83	1.54	2.89
2.5	3.54	1.72	3.23
3.0	4.24	1.89	3.52
3.5	4.95	2.04	3.81
4.0	5.66	2.18	4.08
4.5	6.36	2.31	4.32
5.0	7.07	2.44	4.55
5.5	7.78	2.55	4.79

Application of proposed model

Model calibration

We obtain the probability p_{si} (L, t_i) when there is no witness of type i and the probability $P_c(x)$ when the duration of the crime is shorter than the time interval between witnesses by assigning conditions and values to the proposed model.

The probability p_{si} (L, t_i) varies depending on visible range, traffic volume of witnesses and their velocity. We calculate p_{si} (L, t_i) with Eq. (4) changing visible range, traffic volume and velocity of witnesses. Concerning the velocity of witnesses, V_1=V_3 =4Km/h and V_2=V_4=20Km/h respectively for pedestrians and vehicles. Fig. 6 shows the result of p_{si} (L, t_i) with traffic volume by hour from 1 to 360 and the visible range of 20, 40, 60 and 80m. The graph legends show the velocity of witnesses and visible range. We see from Fig. 6 that for shorter the visible range and the less traffic volume, the probability p_{si} (L, t_i) rises, if the velocity is constant. Furthermore, we see also that as the velocity of witnesses decreases, the value of p_{si} (L, t_i) also decreases.

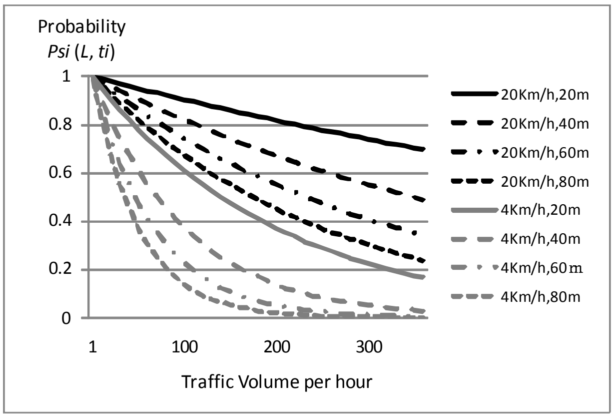

Fig.6 Probability p_{si} (L, t_i) when there is no witnesses of type i

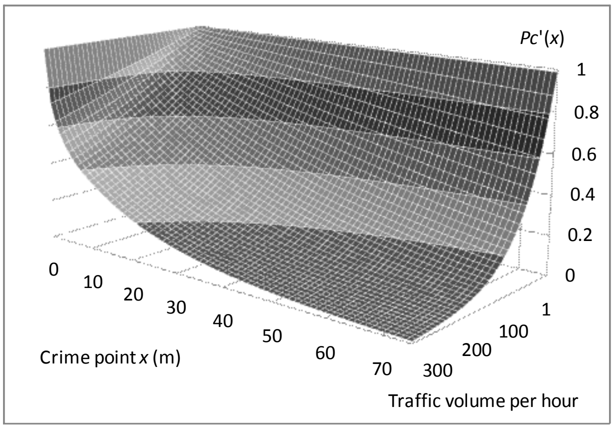

Fig. 7 Distribution of probability $P_c(x)$
(Parameter $\rho(x)$ = 1.0)

Next, we obtain the probability P_c (x) when the duration of the crime is shorter than the time interval between witnesses. The velocity of the criminal is assumed to change continuously between the linear section and the curved section and V_{str} is equal to 20Km/h taking the value of V_{cir} when the crime point x is 7.5m. We calculate P_c' (x) with Eq. (10) changing the traffic volume to V_1=V_3=4Km/h and V_2=V_4=20Km/h as in the case with calculation of p_{si} (L, t_i). We assume that the parameter $\rho(x)$ has the constant value 1.0 for simplification. $P_c(x)$ of each traffic volume is shown at Fig. 7. We see from this figure that the nearer the point x is, the more $P_c(x)$ rises, if the parameter $\rho(x)$ is constant. We see also that for greater traffic volume, the value of $P_c(x)$ decreases.

Outline of applied subject and used data

In this study, we treat the snatch that occurs on a street in a residential district to eliminate the places where the traffic volume and demographical structure are likely to change such as in downtown and business districts. Considering the above, we analyzed the statistical data on snatch that occurred in the residential district of Higashi-ward, Fukuoka City, Japan. Fig. 8 shows an example of a crime scene.

For data, we collected the information on snatches that occurred between January and November of 2004 from Fukuoka Prefectural Police. The information contained times, crime points and criminals' travel mode, etc. This information is in a narrative format based on the offence report. With regard to the crime points, the information includes a description of the surroundings such as a concrete building or facility as well as specific address. Since we plotted the crime

Fig. 8 Example of crime scene

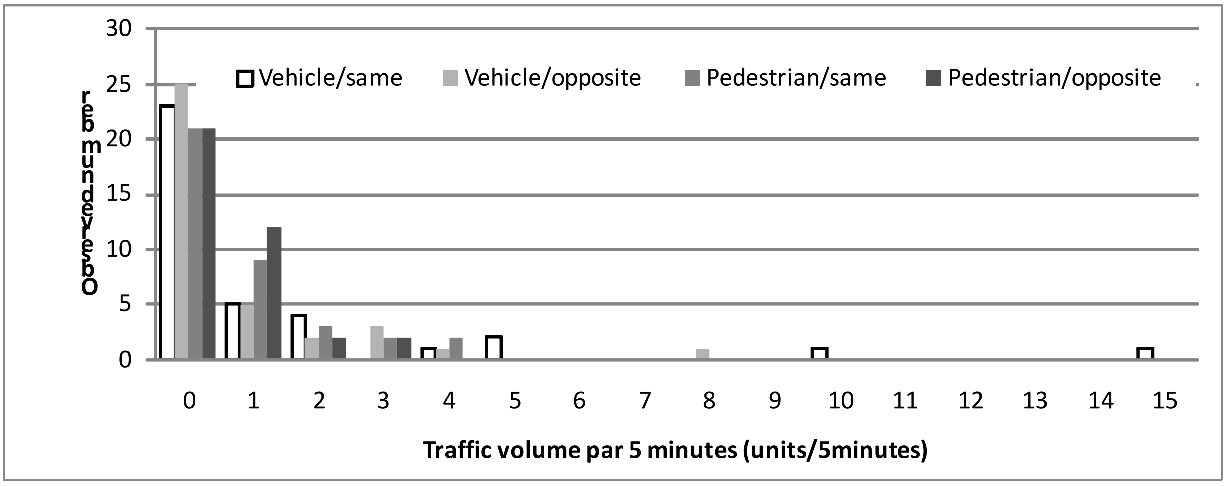

Fig. 10 Distribution of traffic volume per 5 minutes

points on a map using this information, it is possible there is some margin of error. Therefore, we treat the distribution of crime points at intervals of 10m.

According to the data, there were 39 and cases and 21cases of them were identified by their incident times. 70% of these 21 cases occurred between 9a.m. and 5p.m. 37 cases occurred on streets: and among them, 36 cases were streets without sidewalks and 35 cases were straight roads with a good view. Furthermore, all of the criminals used motorcycles. We extracted 37 cases that occurred on streets as objects for application of the model and we took the point x as the distance from the nearest corner, x (m). Fig. 9 shows the relation between crime point x and crime rate. As for road width, presence or absence of sidewalk and road length, we collected this data from a residential map and field survey. Concerning traffic volume, we determined the traffic per 5 minutes as they went through the crime point considering the crime incident time, the mode (vehicle or pedestrian) and direction on 26th January, 2005. The distribution of traffic volume per 5 minutes is shown at Fig. 10.

Result of application

With the intention of calibrating our model, we applied the model to the residential district previously described. We assumed that the velocities V_{str}, V_{cir}, V_1, V_2, V_3 and V_4 are the same as those from the model calibration, and that the visible range is 100m (according to the report from Kakogawa Police Station in Himeji City). For the situation described above, we calculated $P(x)$ for each traffic volume varying the value of parameter α, and then we obtained the distribution of crime points considering the distribution of traffic volume observed by the field survey. As for the parameter $\rho(x)$ influence on the

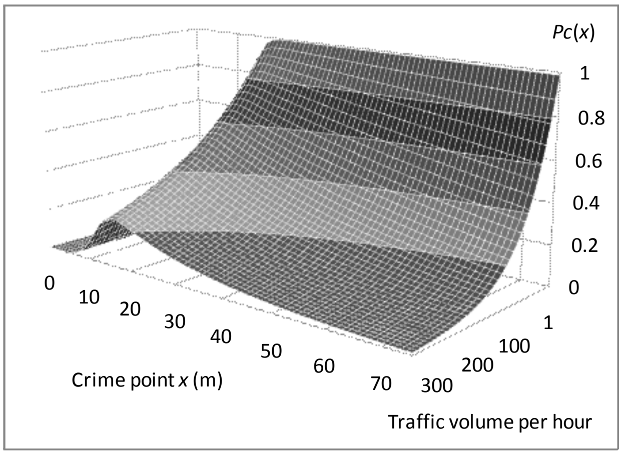

Fig. 11 Relation between traffic volume and $P_c(x)$

(Distribution of $\rho(x)$: Average $\mu = 12.0$, dispersion $\sigma = 7.5$)

criminal, we assumed it to be the CDF of normal standard distribution with average μ=12.0m and dispersion σ=7.5m. On the other hand, we took the PDF $\Phi(P_t)$ as the beta distribution with the parameters q=16.5, r=3.0 and 0□P_t□1 to approximate the distribution of P_t which is calculated from the observed data. Fig. 11 shows the probability $P_c(x)$ which shows that the duration of the crime is shorter than the witness interval time when the average and the dispersion of distribution of $\rho(x)$ are given. Fig. 12 shows the observed CDF of P_t and the approximated beta distribution of P_t. Finally, we estimate the optimal value of parameter α when the error between the calculation and the observation on the distributions of crime points is minimal.

As a result, when α is 0.76, the error between the calculation and the observation of distributions of crime points is minimal.

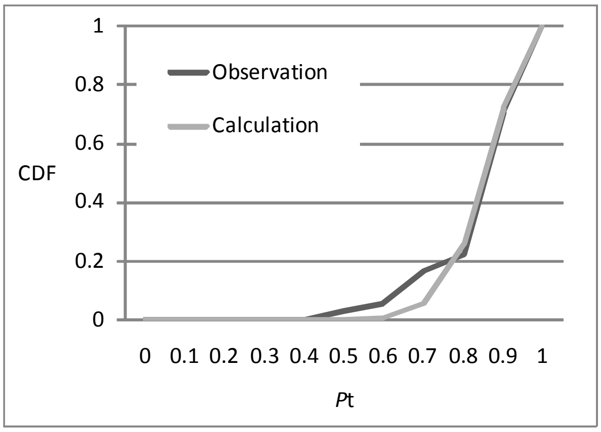

Fig. 12 Cumulative Distribution Function of P_t

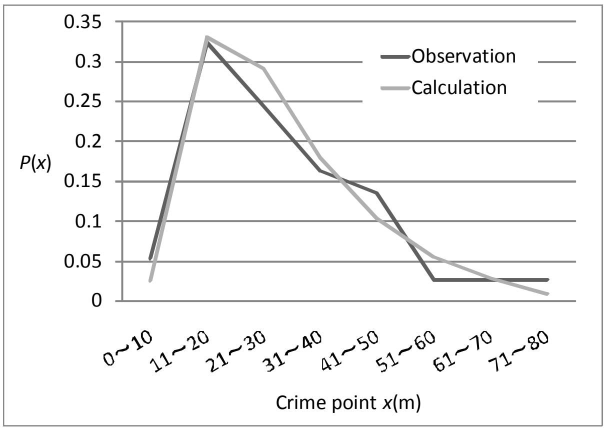

Fig. 13 Distribution of crime point

Fig. 13 shows the calculations and the observations on the distribution of crime points. The significance level of 'goodness of fit' between calculations and observations is approximately 20% according to the Kolmogorov-Smirnov test. Hence one can say that, this proposed model is good enough to describe the incidence of snatch at an arbitrary point on streets.

Conclusion

As a basic step to estimate the effectiveness of anti-crime measures using road network designing and traffic regulations based on CPTED, we presented a proposed model to describe the crime incidence on streets considering traffic volume and visible range. By targeting the snatch in which CPTED works efficiently, we constructed a model using assumptions about criminal behavior based on one of the methodologies of social science.

The proposed model accurately describes the distribution of crime points on streets. Although it is difficult to identify exactly the crime points using the available data and there is also little doubt about the reliability of observed traffic volume, we can say that we obtained favorable result on the methodology of the modelization.

Since the current model can be applied only to a section of a street, therefore, it will be necessary to extend the model to a street network. This extension will make it possible to describe the incidence of snatch considering the influence of street network structure and traffic flow and its findings will provide an important clue to discuss to a quantitative development concerning the deterrent effect of street network designing and traffic regulations on crime.

Acknowledgments: This work is supported by a grant from the Obayashi Foundation and the Grant-in-Aid for Scientific Research (C) (No. 21610014). Considerable assistance was given by Fukuoka Prefectural Police. The authors express sincere appreciation to all.

References

Chinoi, T., Arakida, M., Kitamoto, M. and Koide, O. (2004) "Analysis of the result of the survey about the fear of crime and public participation in maintenance of parks" Proceedings of the annual conference of the Institute of Social Safety Science, No.15, pp.185-188.

Chinoi, T., Himura, K. and Koide, O. (1999) "Analysis on the result of the survey about the location of crime scene and the fear of crime at a housing complex" Proceedings of the annual conference of the Institute of Social Safety Science, No.9, pp. 162-167.

Cohen, L. E. and Felson, M. (1979) "Social Change and Crime Rate Trends: A Routine Activity Approach", American Sociology Review Vol. 44, No.4, pp. 588-608.

Gokita, R. and Ohsawa, Y. (2002) "Safety Range Model Focused on Traffic and Streetlights" PAPERS on CITY PLANNING, No.37, pp.673-678.

Himura, K., Iimura, H. and Koide, O. (2003) "Analysis on the result of the survey about the location of crime scene and the fear of crime at a urban space" Reports of the City Planning Institute of Japan, No.2-1, pp.45-49.

Himura, K. and Koide, O. (1999) "Study on the Spatial Analysis for the Arson" Proceedings of the annual conference of the Institute of Social Safety Science, No.9, pp.156-159.

Hino, K. (2006) "Relationship between Number of Crimes and Land Use: Concerning Burglary in Some Cities of Tokyo" Reports of the City Planning Institute of Japan, No.5, pp.29-32.

Itoh, A., Omi, T. and Ishizaka, K. (1999) "The Relationship between the Occurrence of Opportunity Crime and Spacial Factors of the Urban Environment" PAPERS on CITY PLANNING, No.34, pp.721-726.

Kojima, S. (1978) "Modern Business Administrations Dictionary" Zeimukeiri Kyokai CO., LTD., pp.73-78.

Nagaie, T. and Hokao, K. (2006) "The analysis about the fear of crime by the spatial pattern and regression model – A point of view is put in the time zone and the reason – " Journal of the City Planning Institute of Japan, No.41-3, pp.857-862.

Nagaie, T., Hokao, K. and Inohae, T. (2007) "Analysis of Surveillance and Territoriality on CPTED and relation for the fear of crime – Based on Axial line and Isovist on Space syntax theory –" Journal of the City Planning Institute of Japan, No.42-3, pp. 505-510.

National Crime Prevention Council United States (1997) "Designing Safer Communities: A Crime Prevention Through Environmental Design Handbook": Washington, D.C. , pp. 7.

National Police Agency (2009) "THE WHITE PAPER on POLICE 2009", pp.15

Noda, D., Murosaki, Y. and Takamatsu, T. (1999) "A Study on Crime Prevention through Environmental Design – The Relation between Crime and the Elements of Streets and Path for Pedestrians in the City –" PAPERS on CITY PLANNING, pp.781-786.

Onogi, Y., Hino, K., Amemiya, M. and Obase, R. (2007) "The process of the developments of Security Towns and its problems" Reports of the City Planning Institute of Japan, No.6, pp.33-37.

Popper, K. R. (2002) "the poverty of historicism", Routledge Classics, Routledge: New York, pp.126, 130-131.

Saito, H. T. (1991) "Study of Influence Factor on Crime Prevention at Housing" PAPERS on CITY PLANNING, No.26-A, pp.223-228.

Sueshige, M., Matsunaga, C. and Sumi, T. (2008) "The study on the effect of road network and traffic regulations from the angle of CPTED" PROCEEDINGS OF INFRASTRUCTURE PLANNING, Vol.38, CD-ROM.

Uchida, I. and Onitsuka, K. (1994) "Road Engineering (sixth edition)", Morikita Publishing Co., Ltd.: Tokyo, pp.76-77, 82-84.

Uesugi, S., Hosomi, A. and Kurokawa, T. (1999) "A Study on the Choice Activity of Community Parks Considering User's Anxiety to Crime" PAPERS on CITY PLANNING, No.34, pp.61-66.

Website of Hyogo Prefectural Police Department: http://www.police.pref.hyogo.jp/seikatu/gaitou/hittakuri/index.htm
Website of Wako Bosai Co., Ltd.: http://www.wakobosai.com/index.html