DESIGN OF SHARED-USE SIDEWALKS TO AVOID CROSSING CONFLICTS BETWEEN BICYCLES AND MOTOR VEHICLES AT SMALL INTERSECTION

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ABSTRACT

In Japan, one common bicycle facility is the shared-use sidewalk for bicyclists and pedestrians. By the analysis of traffic accidents between bicycles and motor vehicles, it is found that almost half of these accidents consist of the crossing conflict at the inflow section of the arterial roads with the smaller road. By the analysis of bicycles and motor vehicles movements, it is found that the running path of the bicycle in the sidewalk influences significantly. In order to evaluate the safety, the model was developed by utilizing the data of bicycles and motor vehicles' moving behavior. From this model, it is found that changing the running path of the bicycle is more effective than decreasing their speed up to 5km/h. This result could contribute to consider the design of the sidewalk.

Keywords: Traffic accident, Bicycle, Shared-use sidewalk

INTRODUCTION

Recently bicycles are getting more common by having eco-friendly advantages in many developed countries. However, traffic accidents related to bicycle are increasing in Japan. The number of traffic accidents between bicycles and pedestrians is increasing up to 4 times in the past 10 years. And traffic accidents between bicycles and motor vehicles remain in high counts. It is important to install the effective countermeasures, and needed to reconsider the road spaces for bicycles.

The cause of traffic accident occurrence between the bicycles and motor vehicles is said to be the running spaces of bicycles. In Japan, many bicycles could run in the sidewalk in order to separate the running paths away from the roadway. It is considered that running in the roadway is danger for bicycle compared to that in the sidewalk. Basically, bicycle is a kind of vehicle, and vehicle should run in the roadway. This concept is shown in the Road Traffic

Law in Japan. However, in the 1970's of terrific traffic situation, many pedestrians and bicyclists were seriously injured by the motor vehicles because of the lack of road facilities and poor road infrastructure. Therefore, bicycle could run in the sidewalk in order to separate the running spaces. However, strict rule to design the sidewalk is not installed, there exists many types of sidewalks, such as divided sidewalks for pedestrians and bicyclists by the lane or the different pavement, bare sidewalks that doesn't have any facilities to divide the running spaces (in this case, bicycle could run everywhere in the sidewalk and this brings danger situation for traffic accident between bicyclists and pedestrians) and so on. As controlling the usage of bicycle is not suitable, it is important to install effective countermeasures for bicycles because bicycle is eco-friendly transport and also needed to encourage to use it.

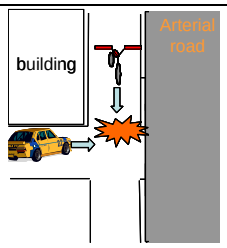
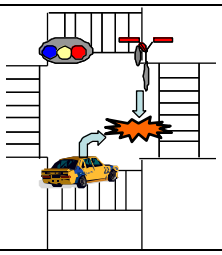
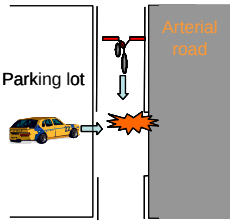
Research on the behavior of the bicyclist has done a lot so far especially in Japan because of the spatial characteristics of bicycle running paths. Bicycle could run in the sidewalk in Japan. Regarding the spatial characteristics of usage of bicyclists in the sidewalk, Koyanagi et al (2000) clarified the current running behavior of bicyclists by their own survey. As a result, most bicyclists have a trend to run the middle of the sidewalk when they run in the higher speed. In addition, Hino et al (2005) clarified the characteristics of bicycle traffic in the sidewalk that allowed running for bicyclists based on the road structure condition. And they also proposed that bicyclists should run in the roadway side of sidewalk in order to separate the running path, angle of the intersection should not have any obstacles to make longer sight distance for both bicyclists and drivers of the motor vehicle, and bicyclist should run in the bicycle lane when crossing the intersection. Namerikawa et al (2005) evaluated the effect of the pavement design from the viewpoint of reducing the running speed of bicycle and controlling the path in the sidewalks.

As described above, there are many researches regarding the bicycle behavior in the sidewalk. However, countermeasures to decrease the number of traffic accidents between the bicycles and motor vehicles has not yet been studied sufficiently.

CURRENT SITUATION OF BICYCLE ACCIDENTS

In order to understand the spatial characteristics of the black spots of bicycle accidents, accident data of municipal police in Akita, that population is almost 300 thousands, was collected and analyzed. Based on the bicycle related accident data for 3 years, 46 black spots are selected for the study. By the result of the survey for each black spot, characteristics were summarized into 3 categories shown in Table 1 (inflow to the arterial roads with the smaller intersection, right-turn situation at the signalized intersection, entrance of parking lot). From this table, it is able to understand that inflow to the arterial road shares almost half. Traffic accidents of the categories "right-turn situation at the signalized intersection" and "entrance of parking lot" are influenced by the volume of traffic. However, there exist many traffic accidents at the inflow to the highway at the situation of the low traffic volume from the smaller road.

Table 1 – 3 categories of black spots

	Inflow to the arterial road	Signalised intersection	Entrance of the parking lot
# of case	21	21	4
Type of intersection			

The spatial characteristics of the intersection for category "inflow to the arterial roads with the smaller intersection" are summarized as follows;

- Smaller road is connected to arterial road
- Motor vehicle runs in the smaller road
- Bicycle run in the sidewalk in the higher speed because of the good road geometry beside the arterial road
- Many traffic accidents occurs when bicycle approaches from the left side of the motor vehicle

The cause of this type of accident is considered as follows;

- Higher speed of bicycle due to the good road geometry
- Driver of smaller road tend not to see the left side of sidewalk but to see the roadway of right side, because motor vehicle in the arterial road runs from the right side to the left side (Vehicle runs left side of the road in Japan)
- Driver tend to stop in front of the roadway, creeping out the pedestrian crossing

These factors makes hazardous situation.

Currently there are not installed any effective countermeasures for this type of intersection. And, the accident occurrence at this type of intersection is now increasing all over Japan. Therefore, there is a need to built up effective countermeasures and install these to this type of intersection.

In this study, focusing on the intersection connecting with arterial road and smaller road, running path of the bicycle and stopping behavior of the motor vehicle are revealed from the video survey, and also, characteristics of the approaching speed of bicycle and motor vehicle are analyzed. From the result of these data, factor that causes to the traffic accident would be clarified. Finally countermeasures to avoid occurring the traffic accident could be clearly established.

OUTLINE OF THE SURVEY

A survey was conducted in order to clarify what kinds of factors, such as the behavior of the bicyclist, affected to the traffic accidents between the bicycles and motor vehicles. In the survey, two locations were selected such as the black spots of the inflow to the arterial roads with the smaller intersection (Intersection A) and the location that is thought to be at high risk of traffic accidents with having almost same geometry as Intersection A (Intersection B). Figure 1 shows the geographical composition of these intersections, and Pictures 1 and 2 shows the photograph of both surveyed sites. In the Figure 1, running path of the bicycle is divided into 3 areas, such as "building path", "center path" and "roadway path", because running path of the bicycle might be the key factor of traffic accident occurrence.

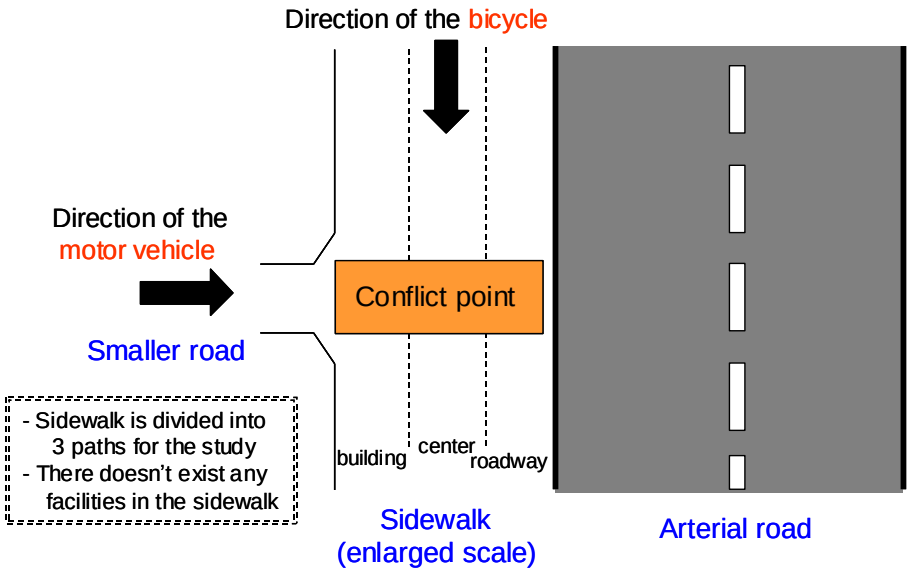


Figure 1 – Geographic composition of intended intersection

Photo 1 – Intersection A (black spot)

Photo 2 – Intersection B

At the survey, two video cameras were used in order to record the speed of the bicycle, the running path of the bicycle in the sidewalk and the location of the motor vehicle stopped at the intersection. One camera was set to overview the running path of the bicycle in the

sidewalk, and the other camera was set to overview the location of the motor vehicle stopped at the intersection. Table 2 shows the outline of the survey.

Table 2 – Outline of the survey

	Intersection A	Intersection B
Date	4, 14, 17 Nov.	15 Sep., 15 Oct.
Time	7:30 -8:30	7:30 -8:30
# of bicycle	192	330
# of motor vehicle	44	31

TRAVELING SPEED AND RUNNING PATH OF THE BICYCLE

Traveling speed of the bicycle

Traveling speed of the bicycle for both intersections were analyzed. Figure 2 shows the average traveling speed of the bicycle for each path from the edge of the intersection. From this figure, it is found that traveling speed of the bicycle does not make a larger slowdown in spite of closer position to the intersection and remain in the higher speed. Therefore, risk of traffic accident would be high because the bicyclist could not stop safely when he recognize the approaching motor vehicle and make a sudden brake due to its higher traveling speed. Also, by comparing the both average traveling speed, Intersection A shows higher speed and this might bring the hazardous situation.

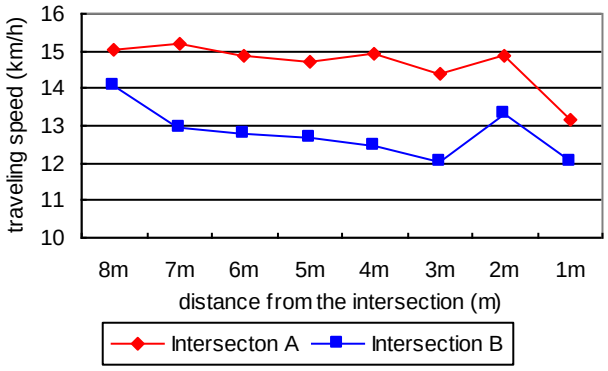


Figure 2 – Average traveling speed of the bicycle

Running path of the bicycle

Figure 3 shows the percentage of each running path of the bicycle for both locations. Running path of the bicycle in the sidewalk was divided into 3 paths. From this figure, it is found that the percentage of running path of the bicycle for "building path" shares as high as 60 percent, while the percentage of running path of the bicycle for "motorway path" shares lower (10 percent) at Intersection A. However, percentage of the running path of the bicycle for Intersection B was almost same in each other. At the situation that the bicyclist run in the "building path", it could be hard for him to recognize the approaching motor vehicle because of short sight distance and also hard for him to avoid traffic accident in spite of performing any kinds of escape behavior because of the smaller margin. Therefore, it could be thought that this situation could influence the traffic accident occurrence, and Intersection A has higher risk of traffic accident.

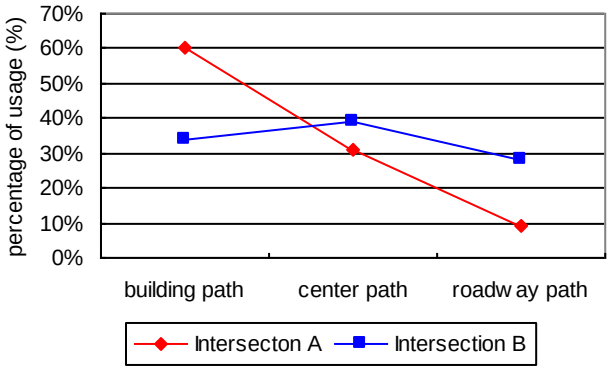


Figure 3 – Percentage of usage for each running path

A hazardous situation of the bicycle due to run in the "building path" could be derived from grade level between the sidewalk and roadway. Figure 4 shows the grade level at the Intersection A. The difference of the grade level at "building path" is smaller than that at "roadway path", and this brings less uncomfortable condition for bicyclists in taking the "building path" of the sidewalk due to the smaller bump in passing though the intersection. Therefore, bicyclists tend to choose "building path" of the sidewalk. This situation has higher risk of traffic accident because of the smaller margin in avoiding traffic accident compared to the "roadway path". Distance between the "roadway path" and "building path" could decrease the risk of traffic accident in running at the "roadway path" because the driver of motor vehicle could have enough space to stop and could avoid the crash.

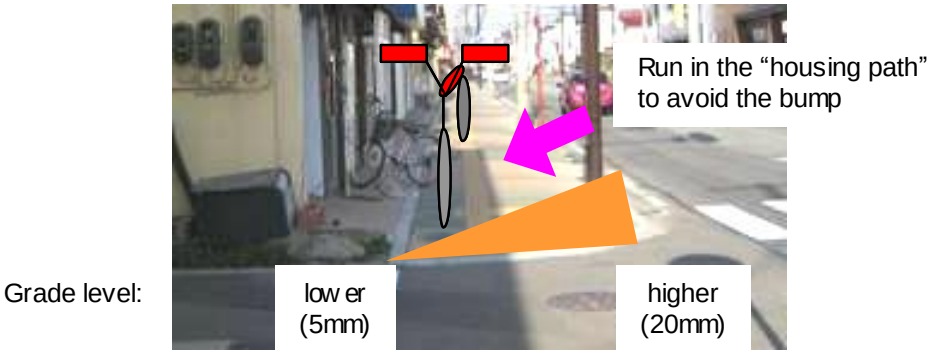


Figure 4 – Grade level at the Intersection A

EVALUATION OF THE RISK

Concept to quantify the risk

Here, risk rate was defined as the probability of accident occurrence between the bicycle and motor vehicle, and risk rate was evaluated for intersection A and B. Percentage that driver could not stop at the conflict point after recognizing the other subject and making a sudden brake for both bicycle and motor vehicle was used in order to evaluate the risk ratio. Risk ratio (D) would be evaluated by multiplying these two percentages (Figure 5). P_b shows the percentages that bicycle could not be stopped with remaining certain spaces in front of the conflict point, and P_c shows the percentages that motor vehicle could not be stopped with remaining certain spaces in front of the conflict point. According to the running path of the

bicycle, conflict point is classified into 3 parts ("building path", "center path" and "roadway path").

$$D = P_b \times P_c$$

D : *risk rate*

P_b : *percentage of impossibility to stop in front of the conflict point (bicycle)*

P_c : *percentage of impossibility to stop in front of the conflict point (motorcar)*

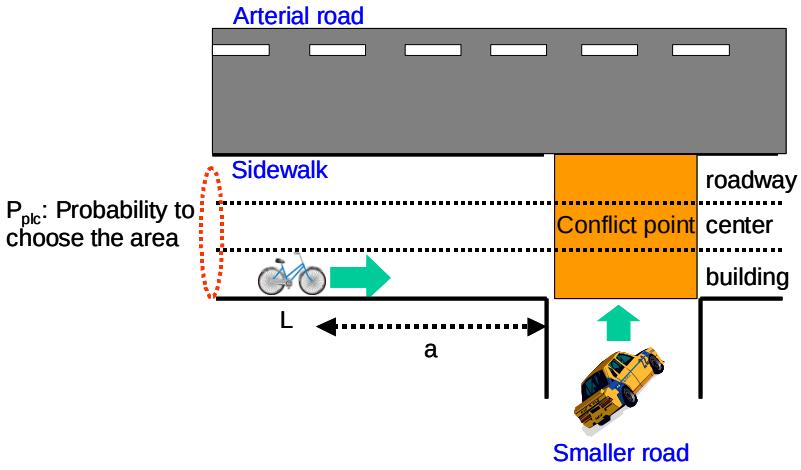


Figure 5 – Concept to evaluate the risk rate

P_b in each conflict point is evaluated by multiplying the probability (P_{plc}) to choose the running path and the probability (P_{ns}) of impossibility to stop in front of the conflict point through the distribution of the traveling speed of the bicycle at each point (Figure 6 and 7). P_{ns} could be calculated every 1m from the conflict point.

$$P_b = P_{plc} \times P_{ns}$$

P_{plc} : *probability to choose the area*

P_{ns} : *impossibility to stop in front of the conflict point*

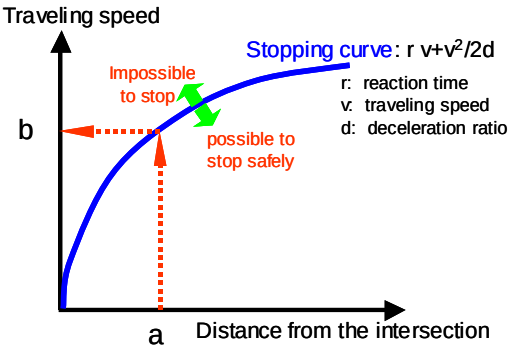


Figure 6 – Traveling speed of border

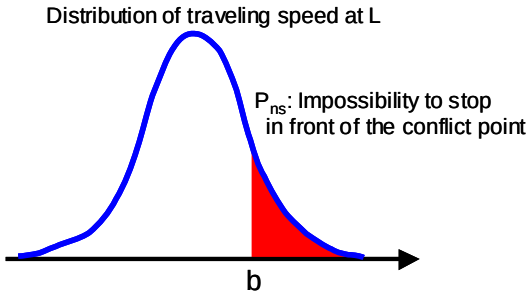


Figure 7 – Probability of impossibility to stop

P_c could be evaluated by utilizing the same concept as calculating P_b. In calculating P_c, distribution of the traveling speed of motor vehicle and distribution of the stopped position of motor vehicle at the intersection were used to show the risk of traffic accident.

Evaluation of the risk

Figure 8 and 9 shows the risk in each position for intersection A and B. Risk is calculated in every 1m from the conflict point. Figure 8 shows that the risk is higher in the "building path" and lower in the "roadway path". In addition, there is a risk of traffic accident within 5m away from the conflict point and there exists fewer risks in the "roadway path". Intersection B shown in Figure 9 has lower risk in "building path" and "center path" compared to the Intersection A. From these figures, it is found that the risk of "building path" has higher risk compared to the other paths. By comparing the risk of "building path" for both intersections, it is clearly shown that Intersection A has higher risk than Intersection B. The reason of this result might come from the higher traveling speed of bicycle and the tendency to stop closely to the conflict point of the motor vehicle in Intersection A.

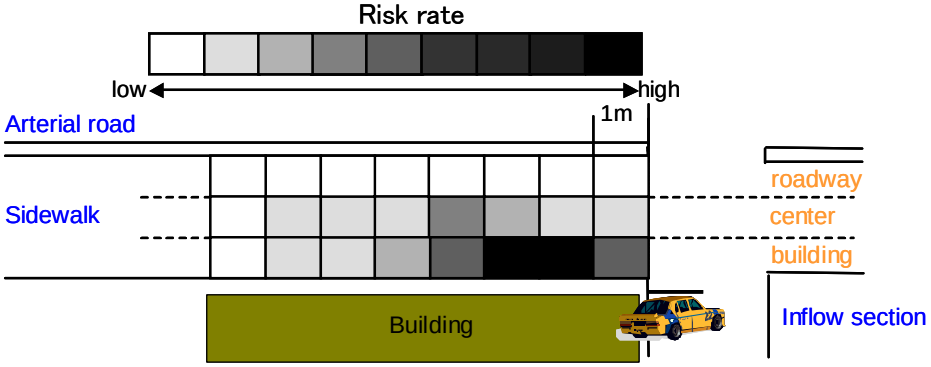


Figure 8 – Risk rate in Intersection A

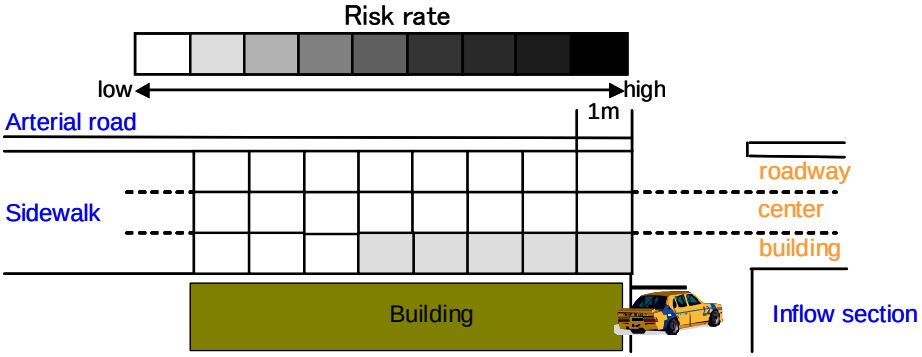


Figure 9 – Risk rate in Intersection B

CONSIDERABLE COUNTERMEASUER

In the former chapter, the risk of traffic accident was evaluated in each path and was compared with both intersections. From the result of this analysis, it could be understood that higher traveling speed and worse running path of the bicycle might be the cause of traffic accident from the bicycle side. In this chapter, the effect of countermeasure is analyzed as how does the risk rate would be decreased if the moving behavior of the bicycle is controlled for several cases.

Effect of decreasing the traveling speed of the bicycle

In this section, higher traveling speed of the bicycle is focused as the countermeasure to decrease the risk of traffic accident. Effect of decreasing the traveling speed of the bicycle is analyzed for Intersection A that has higher risk of traffic accident. Figure 10 shows the risk rate of decreasing 5km/h for all bicycles. This means that all bicycle should decrease their speed up to 2/3 because average traveling speed of bicycle is about 15km/h at Intersection A (Figure 2). From this figure, it could be understood that the effect of decreasing the traveling speed of bicycle is large, and installing this countermeasure would contribute to decrease the risk of traffic accident.

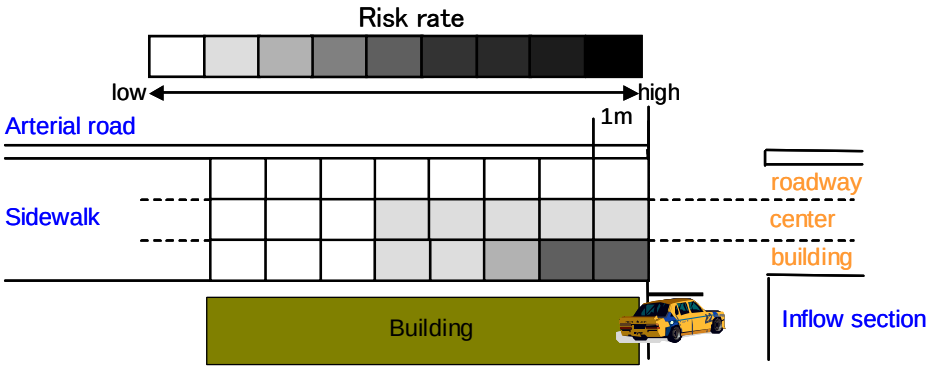


Figure 10 – Change of risk rate in decreasing the speed of bicycle up to 5km/h

Effect of controlling the running path of the bicycle

In this section, controlling the running path of the bicycle is focused as the countermeasure to decrease the risk of traffic accident. There exists higher risk in the "building path" at the Intersection A. Therefore, changing the route of bicycle to the "roadway path" could be one countermeasure to decrease the risk of traffic accident. Figure 11 shows the risk rate with changing the route of bicycle to run the "roadway path" at the position of 4m away from the conflict point. In this situation, it is assumed that all bicycles must take "roadway path" whenever the bicycle approach to the conflict point. From this figure, it could be understood that the risk rate is significantly decreased as the level of Intersection B where there exist few traffic accidents.

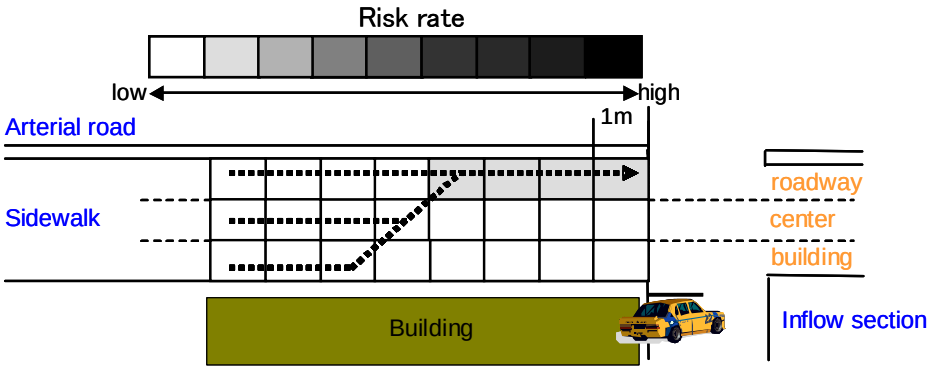


Figure 11 – Change of risk rate in controlling the running route of bicycle

Comparison between the countermeasures

In order to compare the effect of countermeasures shown in the former section, risk rate is summarized as representative value that is a total of each risk rate in the all field of calculated area. Figure 12 shows the ratio of these countermeasures. Current condition of Intersection A is set as 100, and the cases of simulated conditions are shown by the relative score compared to the current condition. From this figure, it is easily understood that changing the route of the bicycle could decrease the risk more than 90 percent, while decreasing the travel speed of the bicycle could decrease the risk about 40 percent Therefore, by taking countermeasures to control the path of the bicycle route could be most effective for decreasing the risk of traffic accident, and it is important to install the countermeasure to change the route of the bicycle at this situation.

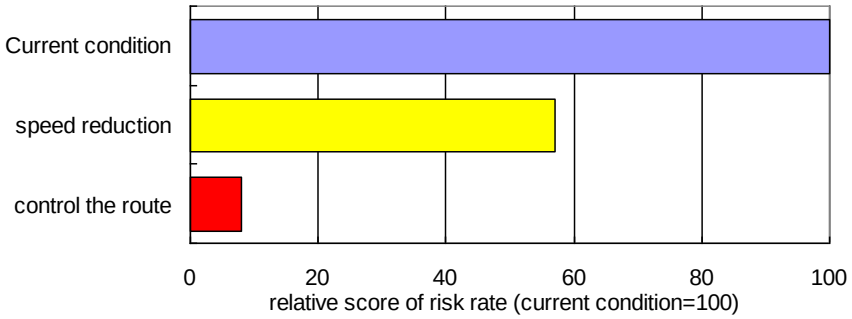


Figure 12 – Comparison of risk rate

Desirable countermeasure

In installing the countermeasure, making the relatively higher grade level to the edge of intersection in the "building path" might be effective to control the route of bicycle. Figure 13 shows the concept of making the grade level at the edge of intersection. There is higher grade level in "building path" and lower grade level in "roadway path". Bicyclists tend to dislike the bump in moving. Therefore, by the installment of this countermeasure, bicycle would naturally take the "roadway path" in passing through the intersection. This could be considered to avoid the traffic accident between bicycle and motor vehicle.

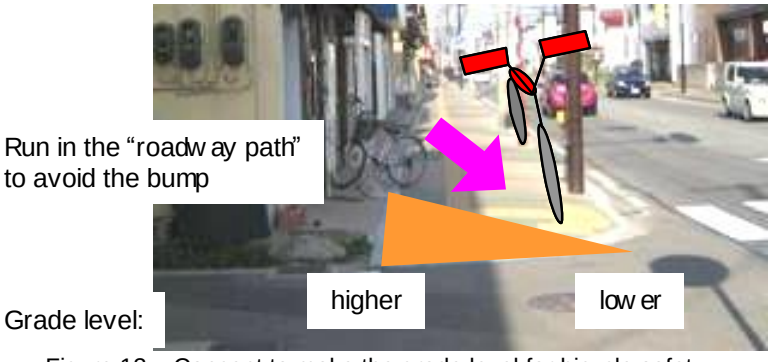


Figure 13 – Concept to make the grade level for bicycle safety

CONCLUSION

In this study, traffic accidents between bicycle and motor vehicle were focused as the significant case for installing the effective countermeasures. According to the black spots of bicycle related accidents in Akita City, it is found that these locations were summarized into 3 categories, such as inflow to the arterial roads with the smaller intersection, right-turn situation at the signalized intersection and entrance of parking lot. Among them, inflow to the arterial roads with the smaller intersection has higher risk of traffic accidents nevertheless that has light traffic from the smaller road. It is important to consider the effective countermeasures to that type of intersection.

By the survey of recording the movement behavior of the bicycle, the cause of traffic accident could be considered as follows; 1) higher traveling speed of the bicycle, 2) worse running path of the bicycle. In order to clarify what influence the risk of traffic accident, risk rate was calculated for each path in the sidewalk. As a result, "building path" has higher risk rate, and this shows that the running path of the bicycle influences significantly.

Furthermore, in order to evaluate the effective countermeasure, the risk rate for changing the traveling speed of the bicycle up to 5km/h and changing the running path of the bicycle to the "roadway path" was calculated for Intersection A that has higher risk of traffic accident. As a result, both countermeasures have certain effect to decrease the risk of traffic accident. By comparing the effect of these countermeasures, it is clarified that changing the running path has more advantages in decreasing the risk of traffic accident. Therefore, it is important to install some method to change the running path to the "roadway path".

In Japan, there is a description that bicycle running in the sidewalk should use "roadway path" in the Road Traffic Law. However, this rule is not kept definitely. It is important for bicyclists to make a consensus to run in the "roadway path". Making the higher grade level to the edge of the intersection in the "building path" is one solution for recognizing the usage of sidewalk.

As the farther direction, it is important to analyze more so as to increase the number of cases that have similar road geometry or bicyle lane.

REFERENCES

Hino, Y., Kamikubo, Y., Yoshida, N. and Ueno, S. (2005): Moving characteristics of the bicycle and its safety by the feature of road geometry at the sidewalk with the allowance to run for the bicycle, Proceedings of the 25th annual meeting of Japan Society of Traffic Engineers, pp.221-224

Koyanagi, J., Kido, T. and Takada, K. (2000): Actual moving behavior of the bicycle in the sidewalk, Proceedings of the 20th annual meeting of Japan Society of Traffic Engineers, pp.149-152

Namerikawa, K., Yamanaka, H. and Nambu, T. (2005): Development of the pavement design in order to control the speed of the bicycle and divide the traffic area, Proceedings of the 25th annual meeting of Japan Society of Traffic Engineers, pp.229-232