AN ANALYSIS OF THE CAUSE OF TRAFFIC ACCIDENTS AT THE BLACK SPOTS

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Abstract
Since 1988, the number of fatal accidents in Japan had consistently exceeded the 10,000 level. The number of fatal accidents decreased below the 10,000 level only in 1996 and 1997. However, the total number of traffic accidents (both fatal and non-fatal) continues to increase, reaching about 770,000 in 1996. This clearly shows that there is a need to understand the causes of traffic accidents and enforce the appropriate countermeasures to decrease the frequency of such accidents. The purpose of this study is to summarize the causes of several types of traffic accidents, and identify the countermeasures needed at the black spots.

INTRODUCTION

Since 1988, the number of fatal accidents in Japan had consistently exceeded the 10,000 level. The number of fatal accidents decreased below the 10,000 level only in 1996 and in 1997. At first glance, this seems to show that the accident condition is getting better. However, the total number of traffic accidents (both fatal and non-fatal) continues to increase, reaching about 770,000 in 1996. The fact that the number of fatal accidents decreases while the total number of accidents increases might show that the countermeasures for minimizing the damage after the occurrence of a traffic accident is already showing fruitful results. Unfortunately, from the viewpoint of cost, although the accident cost for fatal accidents may decrease due to the declining number, the total accident cost is still high because the total number of traffic accident is about 800 times as much as the number of fatal accidents. Furthermore, there are instances when accidents bring about heavy traffic congestion, adding more indirect costs. This clearly shows that the problem of traffic accident is still serious in Japan.

Japanese traffic accident statistics show that 9% and 7% of the total number of road mid-sections and intersections, respectively, are considered black spots. Within these black spot areas, in spite of the low percentages given above, more than half (54%) of the total number of road mid-section accidents and about a third (29%) of the total number of intersection accidents occurred. The Japanese Ministry of Construction (MOC) and the National Police Agency (NPA) collected accident data for national and major arterial roads (excluding the expressway) within a 4 year period from 1990 to 1993. Utilizing this database, MOC and NPA identified 3000 black spots characterized by the following conditions: (1) more than 2 fatal accident happened, (2) more than 24 accidents happened, and (3) the index of latent fatal accident is more than 0.4. These imply that there is a need to understand the causes of traffic accidents at black spots and enforce the appropriate countermeasures to decrease the frequency of such accidents.

In the analysis, the GIS database previously developed by the author was utilized. Using the tool, the geological location of traffic accidents and cross-classification by accident type in the study area was understood.

The purpose of this study is to summarize the causes of traffic accidents at black spots from the viewpoint of field survey, identify the countermeasures needed at the black spot areas, and propose better standards for road construction. To accomplish these, at first, black spots are selected in the study area considering the number of total accidents and also by each type of traffic accident. Secondly, the causes and types of traffic accidents that happened at the black spots are explained by the result of comparative analysis of information gathered using GIS and field survey. Thirdly, black spots are divided into several groups according to causes of traffic accidents. Fourthly, experiments on drivers' eye movement are conducted to understand the causes of traffic accidents from the human psychological point of view at specific black spots. The experiment interestingly revealed that it is safer for drivers to cross an intersection where they can not see the other road as compared to crossing an intersection wherein a driver could see the other road but with restricted visibility. Finally, a summary of the causes of traffic accidents and the desirable countermeasures at the black spots is given.

STUDY AREA AND DATA

Study area

Study area of this study is Aoba Ward, Yokohama City where a GIS database had been previously developed. In analyzing the cause of traffic accident, information around the black spots is very important and must certainly be considered. The cause should be investigated from various points of view. Because GIS is a very helpful tool in explaining the characteristics of black spots, the fact that a GIS database for the study had been developed is a good advantage for this study.

The size of this study area is about 35 square kilometers, and about 250,000 people live in this study area. In terms of the road network, various kinds of roads are within the area, including national and major arterial roads. However, expressways are excluded from the investigation because the cause and situation of traffic accident is very much different compared to roads wherein the paths of pedestrians and vehicles are not separated.

Characteristics of the GIS developed in this study

Data such as road network, accident reports from the local police, land use from the urban planning map, road geometry (slope, width, curve, etc.) from the large-scale map and field investigation, traffic environment (traffic flow in the arterial road, the number of roadside parking and traffic signals , etc.) were included in the previously developed GIS database.

In this GIS, two kinds of accident data were integrated. The first kind of data is accident report listed in numerical codes representing the characteristics of accidents, while the other kind of data are those whose accident locations were manually recorded and mapped by policeman on residential maps with a scale of 1:1500. The ratio that the data for both kinds of data sources matched is about 50%. The reason is that there were a lot of missing data in the manually mapped data compared to the coded accident report due to the large number of accident occurrences in the study area.

Figure-1 shows the comparison of selected accident ratios in each road type. From the figure, it is easy to understand that the selected ratio for major arterial road is about 1.5 times as high as the other. This shows that in this GIS database, accidents occurred in major arterial roads more than those in residential roads.

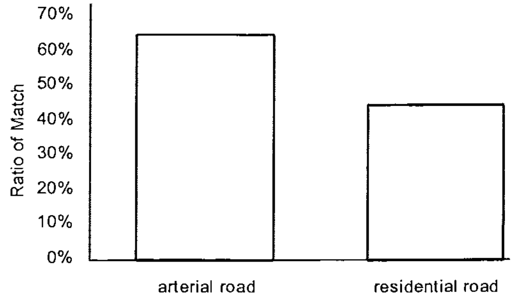

Figure 1 – Ratio of match in each road

Figure-2 shows selected ratios for different months. This figure shows that the selected ratio is varies for every month, and that there are some months when there are no matching data. The possibility that there are some months when accidents do not occur should not be forgotten during the process of comparison.

By using GIS, it is possible to understand the location of accidents according to type, date and time of occurrence, and so on. Identifying which intersections are considered black spots becomes much more easy.

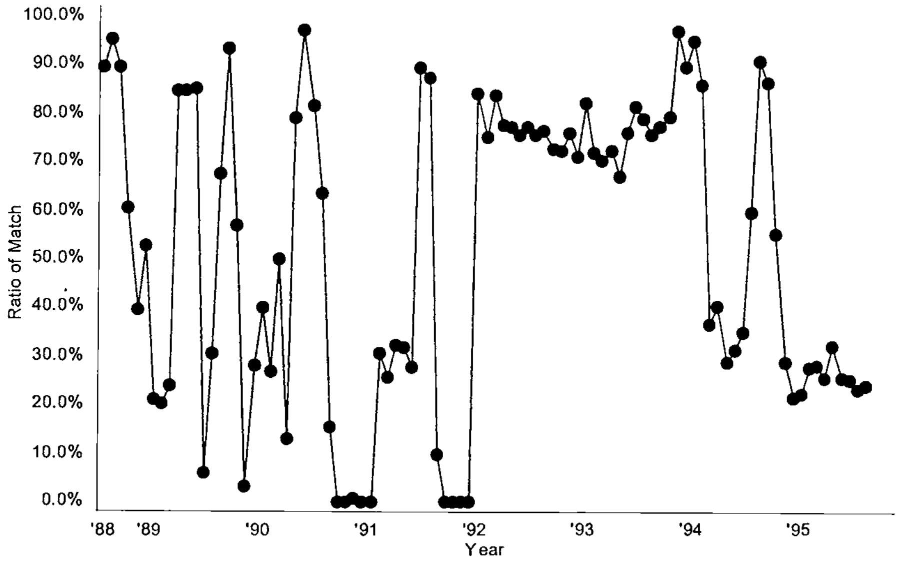

Figure 2 - Ratio on match in each month

Black spots

Only accident which occurred at intersections were used in this study. There are two reasons for this. First, more than 60% of accidents happened at the vicinity of intersections. The second reason is that understanding intersection accidents is easier compared to accidents at road mid-sections. Intersection accident records included in the study were selected based on considerable cause.

In this study the black spots were selected from the available GIS output. It was discovered that the black spots for rear-end collision type of accidents were concentrated at trunk roads characterized by downward slopes. The location of crossing-conflicts were dispersed but closer investigation revealed that the black spots tended to be located at several minor intersections having poor visibility and inadequate sight distance.

SUMMARY OF THE CAUSES OF ACCIDENTS AT BLACK SPOTS

Characteristics of accidents at black spots

Figure-3 shows information on accidents that occurred at different intersections sorted by number of accident. It can be seen that some intersections exhibit higher occurrences compared to most other intersections. It can be deduced that black spots exist in the study area. From the figure black spots are selected where the number of accidents is more than 12 (1.5 accidents per one year). The percentage of the number of traffic accidents at black spot is 43% (1,539 accidents) while the percentage of black spots is only 2.6%.

Figure-4 shows the location of black spots identified from the previous procedure. It can be seen that there are cases where accident locations are found close together but one location exhibit more accidents than the others. By looking closer into such cases, the cause of the accident at the block spot can be understood.

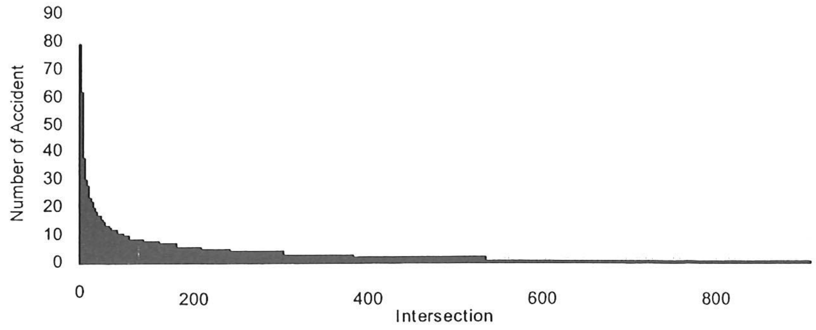

Figure 3 – Number of accident at intersection

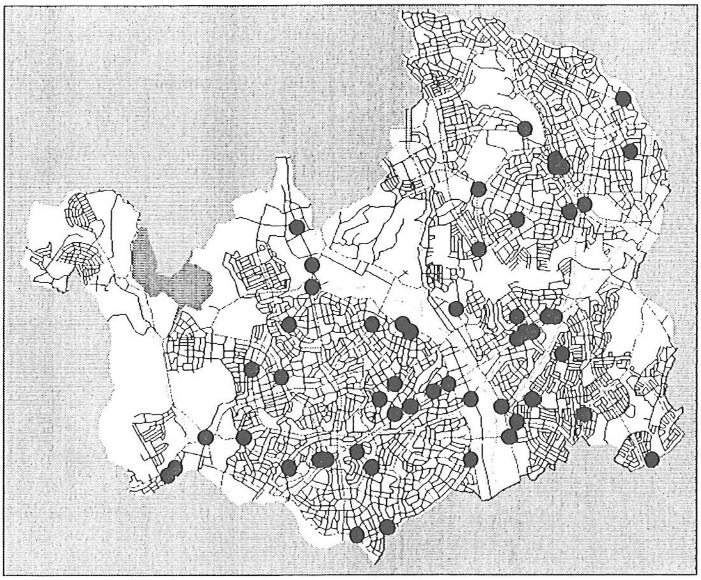

Figure 4 – Black spots in this study area

Cause of traffic accident by type

Considering the cause of traffic accidents at black spots by the number of occurrences is not effective because the type of accidents varies greatly. Thus, at first, the black spots are classified into several groups by accident type (crossing conflict, rear-end collision, etc.), and then the cause of accident is considered for each accident type.

Crossing conflict

Figure-5 shows the black spots where many crossing conflict occurred. From the result of field survey and GIS data analysis, it was discovered that the cause of crossing conflict could be separated into several groups, such as poor sight distance due to roadside object, poor sight distance due to road geometry, lack of hierarchy between intersecting roads, and so on.

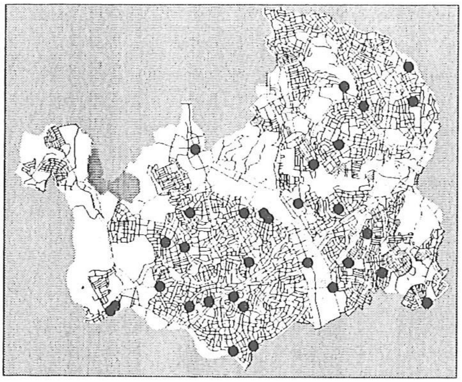

Figure 5 - Black spots in this study area (crossing conflict)

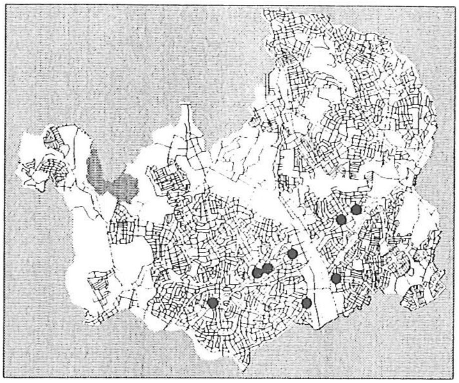

Figure 6 - Black spots in this study area (rear-end collision)

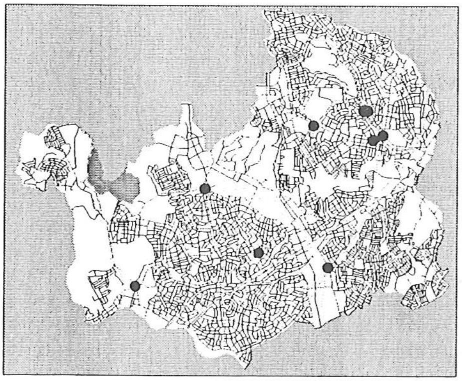

Figure 7 - Black spots in this study area (right-turn collision)

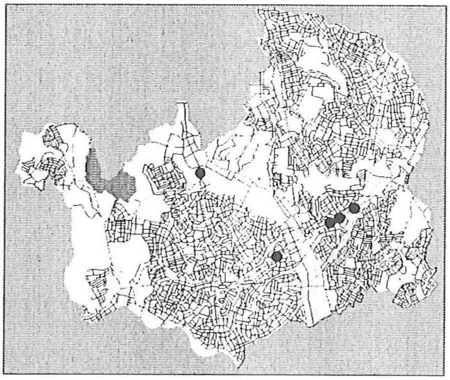

Figure 8 - Black spots in this study area (left-turn collision)

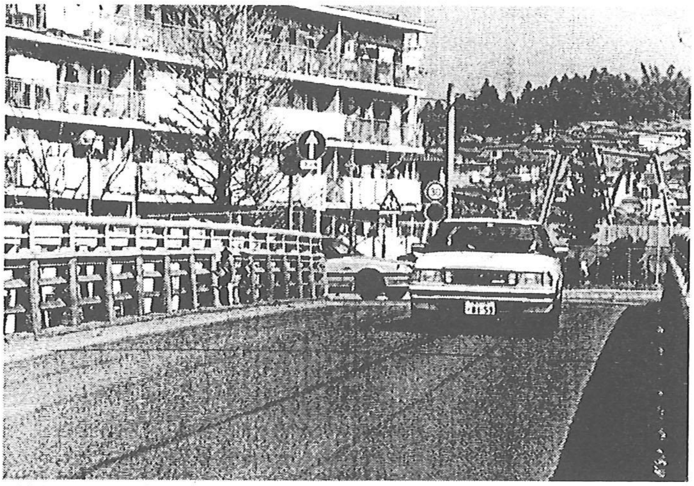

Photo 1 – Typical black spot (crossing conflict)

Poor sight distance due to roadside object

Railing of the bridge, raised track of rail, or automatic vending machines could decrease the sight distance for drivers (Photo-1). The photo shows a location along a road that is used as a secondary path due to congestion along the first path. Because of this, the traffic volume is rather high compared to the road located nearer. Speed is also rather high because some drivers run this road as if they are driving along a major arterial road.

In such situations, it is important to consider the location of roadside objects so as not to hamper the sight distance of drivers.

Poor sight distance due to road geometry

Horizontal curve on the road makes sight distance critical to the drivers. An intersection located just at the end of a curve is therefore not easily perceived by the driver. To design the intersection around the curve area is not good for the viewpoint of sight distance. Such design must be prevented and locating the intersection at another section along the road must be considered.

Poor sight distance due to roadside parking

There are many cases of roadside parking in commercial areas, and this also brings about crossing conflict due to the poor sight distance. It can be seen that roadside parking make the driver feel that there is no intersection ahead. In these places, poor sight distance plus the effect that drivers feel that there is no intersection ahead creates a potential cause for an accident to occur.

Plants along the street

In newly developed areas, there are many plants (trees) along the streets. This can make the driver feel better, but sometimes the vegetation obstructs the view of the traffic signals making it difficult for the driver to see. It is important not only to make the street with plants but also to maintain the growth of such greeneries.

Lack of hierarchy between intersecting roads

There are many cases of controlled urbanized areas. In these areas, there are few roads that are newly constructed because almost all developments are restricted. So there exist many old-styled roads with similar widths intersecting each other. At such intersections, the road having the priority to cross first is not clear because the road hierarchy is also not clear. This lack of obvious crossing priority brings about a large number of crossing conflict. At such areas, road hierarchy must be clearly established.

Effect that driver could not find the intersection

There are many cases in the arterial road where road geometry is good. Because geometry is good, driver tends to run in the high speed, and this makes driver difficult to perceive small intersections. In this case, the median can sometime create for the drivers the effect that the road is straight and there are no intersections ahead. It is important to consider this effect for the driver so that drivers can see and be aware of all intersections easily.

Rear-end collision

Figure-6 shows the black spots where many rear-end collision occurred. As the result of field survey and GIS data analysis, it was found that the cause of rear-end collision could be separated into 4 groups, namely, gradient of the road, curve of the road, intersection in the high speed road and weaving section.

Gradient of the road

There are many cases where traffic signals are located at the end of a downward slope. It can easily be understood that rear-end collision could easily occur because of the diminished effect of breaking due to the downward slope. Sometimes drivers could not even realize that he is in the slope section at that time. It is important to inform the driver that he is in the slope section so that he can decrease the speed of the car. The current phase of traffic signals must also be informed clearly.

Curve of the road

Typical cases of this accident occur at places where the intersection is at the end of curve section. In this case the car ahead stops because of the red signal of intersection, however, the following driver could not immediately realize that the car ahead stopped at the intersection because of the sight restriction caused by road geometry (curve). This case creates a great danger that accidents will occur. In some intersections, there is a supplemental traffic signal in order to inform the current phase of traffic signals to the drivers at the back of the stream.

Intersection in high speed road

It is not easy to stop within a short distance at high speed roads. The difference between the speed in running and speed in stopping is substantial in this situation. It is difficult to shift quickly from high to low speed. When a driver runs at high speed, the available time for the driver to perceive the intersection ahead, step on the break, and finally stop is very constrained compared to a driver running at a lower speed. It is important that the driver is informed early of the current phase of signal at the intersection ahead.

Weaving/Merging area

For weaving/merging areas, an interesting situation was revealed from the analysis of GIS data. It was observed for the case where drivers from a minor road or ramp tries to merge into the main or trunk road traffic stream. As the driver of the lead vehicle waits for an acceptable gap to enter the trunk road stream, the next driver also anticipates his merging, and thus becomes more attentive to the vehicles along the main road instead of the vehicle in front of him. Thus, rear-end collision can easily occur between the following vehicle and the lead vehicle.

Right-turn collision

Figure-7 shows the black spots where many right-turn collision had occurred. As the result of field survey and GIS data analysis, it was found that the cause of right-turn collision could be separated into 2 groups, namely, road geometry and right turning cars face-to-face with opposite cars also turning right.

Road geometry

This is for a case where intersection is located at a curved road. Because of the bend in the road, there is difficulty for right-turning drivers to see approaching and conflicting thru vehicles from the other road. Collision can easily occur especially when volume is low, and right-turning drivers make their turn before they are given the green signal. Rear-end accident mainly occurred for the observed intersection.

Right turning cars face-to-face with opposite cars also turning right.

This type occurs primarily at large intersections where there are many right-turning vehicles. At such intersections, it is common that right-turning vehicles from opposite streams wait inside the intersection such that the lead vehicles are opposite each other, face-to-face, waiting for an acceptable gap in the crossing thru traffic before making their turn. The opposite right-turning vehicle can sometimes obstruct the line of sight of the driver also wanting to make a right-turn from the opposite stream, thus making his turn unsafe. This can lead to rear-end accidents. For large intersections, it is important that sight distances for both opposite directions be kept adequate.

Left-turn collision

Figure-8 shows the black spots where many left-turn collision occurred. As the result of field survey and GIS data analysis, it was found that the cause of left-turn collision is escape from the trunk road.

Escape from the trunk road

The major type of left-turn collision is between a car and a motorcycle. There are also many accidents which occurred at trunk roads during traffic jams.

Accident of this nature occurs when a driver, initially wanting to use a trunk road finds himself caught in a traffic jam. Wanting to escape the trunk road through a minor road downstream, the driver suddenly weaves out of the congested stream and wanting to make a left turn to the minor road becomes unaware of an approaching motorcycle on the lane to his left. Thus, a collision occurs.

Summary of accident causes

There are many accidents whose causes are attributed to poor sight distance. With respect to poor sight distance, there are yet many sub-causes identified and explained above. These sub-causes can be further summarized by re-grouping the accident records by sight distance causes. Data were regrouped into 2 axes. That is, whether they were moving or not moving when they were deciding their action and assessing the change in surrounding environment around the intersection. Table-1 shows the result of arranging the cause of accident at the black spots.

Table1 - Result of arranging the cause of accident at the black spots

Movement **Change the surrounding environment** ●Roadside parking (crossing conflict) ●Street plant (crossing conflict)	**Non-movement** **Change the surrounding environment** ●Car turn to the right (right-turn)
Movement **No-change the surrounding environment** ●Road geometry (crossing conflict) ●Roadside object (crossing conflict)	**Non-movement** **No-change the surrounding environment** ●Median (right-turn) ●Road geometry (right-turn)

There is a need to conduct traffic observation to understand the degree of how diminished sight distance can be a cause of accident, and clarify the reason why such kind of accident occurred.

CASE STUDY

Study area

In this study a place (Photo-1) was chosen in order to understand the cause of accident with respect to sight distance. The location of course is the one of the black spots identified earlier in the study. There are many crossing conflicts in this area because drivers who pass this area have difficulty seeing that there is an intersection after the railing because the railing casts a shadow towards the intersection. At this intersection, there is a curve mirror in front of the intersection in order to check the approaching car easily for the driver who want to turn right and enter that road.

Data collection

Three kinds of data should be collected to consider the cause of traffic accident at the black spot. Firstly, it is important to understand the geometric condition around the intersection. To understand this, the location of curve mirror and sight distance was measured. Secondly, to understand the current traffic situation, the speed of vehicles that pass this intersection and the time it takes to turn right was collected. Finally data of drivers' actual action was collected. In this study, eye-mark-recorder was used to understand the drivers' behavior in turning right at the intersection. From the eye-mark-recorder, the point that a driver watched and fixed his gaze was recorded on video tape every 1/30 seconds.

Traffic flow analysis

Comparison between the traffic flow and driver action

Figure-9 and Firure-10 shows the procedure used to understand the ratio of danger at this study area. Firstly, the location where the driver of the right-turning car decided to turn was checked. Also, the sight distance from this point to the approaching car that passed the intersection was measured. Secondly, the distribution of time needed to make the right turn was collected. Then the marginal speed needed so as not to collide with each other was obtained to make a comparison. Finally, the speed distribution of vehicles passing the intersection was determined. By comparing the computed and measured speed and distance parameters it was possible to calculate the ratio of danger when the speed surpasses the marginal speed.

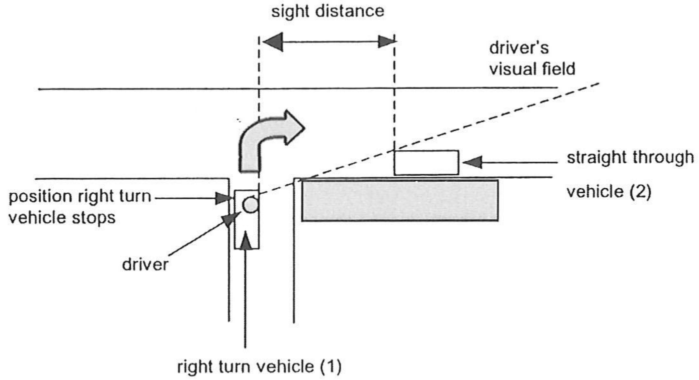

Figure 9 - Procedure to understand the ratio of danger (1)

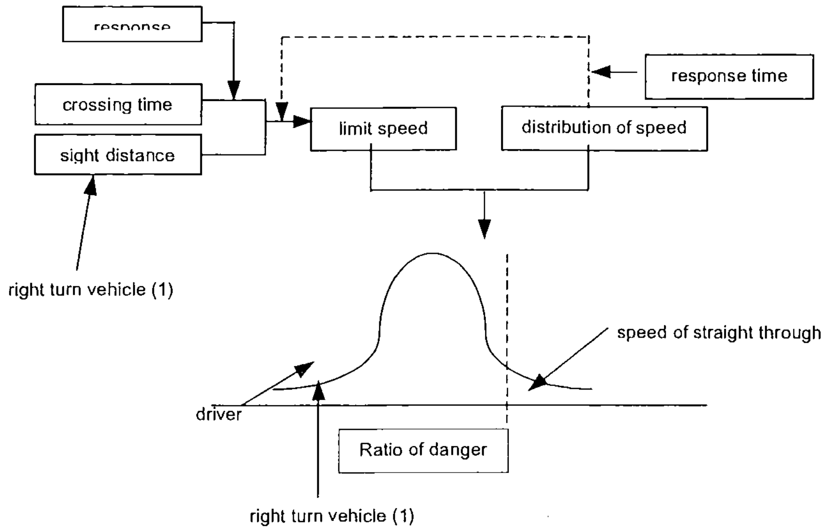

Figure 10 - Procedure to understand the ratio of danger (2)

Analysis of the drivers' eye movement

To understand the eye movement of drivers, the experiment on drivers' eye movement was conducted. To monitor the eye movement, the point where a driver fixed his gaze was recorded every 1/10 seconds. The result of eye-mark-recorder analysis shows that the driver is more preoccupied in watching the approaching car through the railing. Although the curve mirror was in front of the driver, the driver almost did not look at it to check if cars are approaching.

Figure-11 shows the ratio of danger calculated based on the sight distance and distribution of the speed. It is easy to understand that the ratio of danger in the current situation is high compared to the situation where all drivers only check the approaching car through the curve mirror. If all drivers use only the curve mirror, the ratio of danger will decrease up to 1/8.

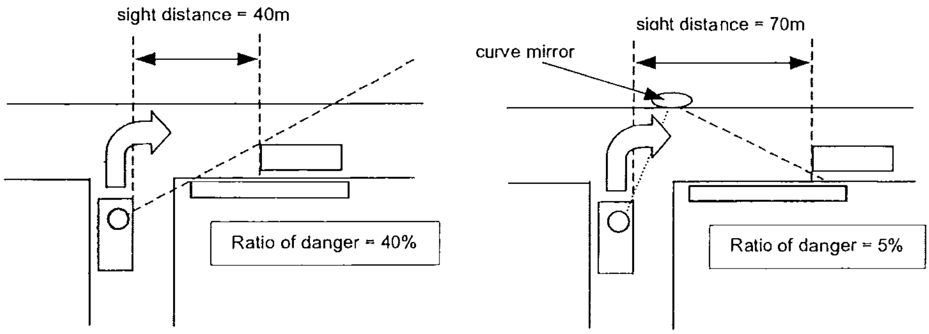

Figure 11 - Ratio of danger in each case

The study of this intersection showed that the ratio of danger due to poor sight distance is high. It is important that a countermeasure to design a longer sight distance be proposed. In this case, as supported by the result of the eye movement experiment, it would be a better countermeasure to erect a wall fully obstructing the line of sight for the approaching car so that the curve mirror will be fully utilized and therefore be safer, than to replace the railing to improve visibility (but still partial) of approaching cars.

CONCLUSION

In this study, the need to know the existence of black spots and understanding the cause of accidents at black spots are shown through recent trends and through the GIS output previously developed. Using the GIS, it was discovered that the black spots for rear-end collision type of accidents were concentrated at trunk roads characterized by downward slopes. The location of crossing-conflicts were dispersed but closer investigation revealed that the black spots tended to be located at several minor intersections having poor visibility and inadequate sight distance.

In the analysis, black spots were cross-tabulated by location and accident type. In detail, the study further investigated the following: (1) the common factors of traffic accidents among the black spots, (2) comparison of the characteristics between black spots and non-black spots in spite of having the same road geometry, and (3) the characteristics of traffic accidents at the black spots related to the road condition and environment.

From the output of the case study, it is understood that drivers decide to turn right after checking the approaching cars through the railing that gives less visibility rather than using the curve mirror. Thus, one possible countermeasure is to discourage the drivers to look through the railings instead of the curve mirror by fully cutting the line of sight through the railings.

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