３．２．２　交通事故に関する研究

Analysis of Correlation between Roadway Alignment and Traffic Accidents

By

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ABSTRACT

As roadway alignment has a significant impact on the drivers on roads, careful consideration must be given to road alignment in order to reduce road accidents. Sharp curves and steep grades, for example, are known to increase the potential for accidents, and should be avoided wherever possible. In addition, the frequency of traffic accidents may vary even on roads with the same alignment if their facilities or the configuration of their cross sections etc. differ. Thus, in designing the road alignment to minimize road accidents, it is necessary to also consider the placement of facilities and the configuration of the roadway cross-section. This report seeks to provide valuable information for use in the road alignment design process by analyzing correlation between road alignment, traffic conditions and road accidents. One example of the findings of this study involved a comparison of the lane deviation accident rate on curves on four-lane roads and two-lane roads. The comparison revealed a higher accident rate on two-lane roads, and also found that the smaller the radius of curvature, the higher the accident rate, particularly on two-lane roads. In this way, a great deal of new knowledge has been obtained.

1. INTRODUCTION

As roadway alignment has a significant impact on the drivers and drivers' behavior on roads, careful consideration must be given to road alignment in order to reduce road accidents. Sharp curves and steep grades, for example, are known to increase the potential for accidents, and should be avoided wherever possible.
Compared to curves in non-urbanized districts where there are no roadside facilities, drivers may be less attentive on curves in urbanized districts where there are shops and other roadside facilities. As a result, drivers tend to enter these curves at higher speeds. Thus, accidents may occur more frequently on the latter type. In this way, the frequency of traffic accidents may vary even on roads with the same alignment if their facilities or the configuration of their cross sections etc. differ. This means that in order to select a road alignment that will not increase the potential for traffic accidents, it is necessary to pay attention to the way that facilities are placed and on the configuration of their cross sections. This study focused on the impacts of roadside situations, number of lanes, and the placement of traffic safety facilities to analyze the relationship between road alignment, its plane alignment in particular, with the occurrence of traffic accidents so that designers can design road alignments considering these points. This paper reports its results.

2. THE DATA USED AND THE ANALYSIS METHOD

The analysis was performed using the Integrated Traffic Accident Database and the MICHI Data Base (Road Management Database).
The Integrated Traffic Accident Database was created by combining the Traffic Accident Statistical Data and Road Traffic Census Data. The Traffic Accident Statistics Data are records of data concerning each traffic accident causing death or personal injury: for example, the type of accident, type of people involved, time period (daytime, nighttime). The Traffic Accident Statistics Data include data concerning all accidents that caused fatalities and/or personal injury in Japan. The Road Traffic Census Data are records of the traffic volume, percentage of large trucks, degree of congestion, and roadside situations in road sections, etc. The Road Traffic Census Data includes information about all sections on national highways and on prefectural roads. The MICHI Data Base records data concerning the geometrical configurations of roads and the placement of road side facilities in all road sections. The MICHI Data Base records data concerning roads managed directly by the Ministry of Land, Infrastructure and Transport (21,828km in 2001).
The above data are integrated using location information (road numbers, kilometers from the origin points of each road) as the key data. This data base can be used to clarify the correlation of the state of the occurrence of traffic accidents, traffic volumes, roadside situations, geometric configurations of roads, placement of road side facilities, and so on. Intersection accidents have been omitted because the characteristic of intersection rather than roadway alignment affects the cause of traffic accidents at intersection.
Data for the four-year period between 1998 and 2001 was used for analysis. In addition there is no data of Property Damage Only (PDO) accident statistics in Traffic Accident Statistical Data in Japan. Thus, the analysis was based on accidents involving death and injury, not PDO accidents.
In this report, the state of the occurrence of traffic accidents is, the accident rate. This eliminates the effects of differences in traffic volumes. The accident rate AR (accidents/100 million vehicle km) is calculated as shown in the following equation when the number of fatal and personal injury accidents is NA (accidents/year), the traffic volume in the same section is Q (vehicles/year), and the length of the section is L (km):

$$A_R = \frac{N_A}{Q \times L}$$

3. RESULTS

3.1 Correlation of radius of curvature with the accident rate

As the basic analysis, the correlation of the radius of curvature with the accident rate was analyzed (Figure 1). It revealed that the smaller the radius of curvature, the higher the accident rate. But if the radius of curvature is equal to or above a certain value, even if the radius of curvature increases, the accident rate tends to rise instead of falling. An analysis of the correlation of the radius of curvature with the accident rate by type of accident has revealed that the smaller the radius of curvature, the higher the accident rate of the accidents caused by the deviation of a vehicle

from its lane such as head-on collision, vehicle alone (Figure 2). When the total number of accidents caused by deviation of a vehicle from its lane (vehicle to person walking facing/parallel to vehicle (not on the roadway), head-on collisions (except while passing or overtaking), collisions with structures, and running off the road) is examined, this tendency is even more pronounced. This is presumably a result of the fact that the smaller the radius of curvature, the more likely a vehicle is to deviate from its lane under a physical effect such as centrifugal force.
In contrast, the larger the radius of curvature, the higher the rear-end collision accident rate, presumably because when the radius of curvature is large, drivers feel safe, and are consequently less attentive. If drivers' attentiveness declines, accidents caused by vehicles deviating from their lanes should also increase, but they actually decline. It is assumed that lowering the centrifugal force sharply reduces lane deviation accidents, and that this reduction exceeds the rise of the number of accidents caused by drivers' inattentiveness. So it is assumed that this markedly increases only those accidents not caused by a vehicle lane deviation, particularly rear-end collisions.

3.2 Correlation of radius of curvature with accident rates by roadside situations

The correlation of the radius of curvature with accident rates by road side situations was analyzed (Figure 3). The roadside situations were categorized as "DID", "other urbanized districts," and "non-urbanized districts" (See Table 1 for the definition of each category). Regardless of roadside situations, the smaller the radius of curvature, the higher the accident rate. It also clarified that regardless of the radius of curvature, the accident rate in DID is highest, and the accident rate in non-urbanized districts is lowest.
Next, the correlation of the radius of curvature with the accident rate was analyzed by roadside situations by type of accident (Figure 4). It revealed that in DID and other urbanized districts, the percentage of all accidents that are rear-end collisions is extremely high at about 50%. This high rate is a result of vehicles suddenly decelerating when other vehicles enter or leave the many facilities accessible along roads in DID and other urbanized districts. Signboards etc. along roads are assumed to also lower drivers attentiveness to their driving.
In non-urbanized districts on the other hand, the percentage of all accidents that are rear-end collisions is not as high as it is in DID and in other urbanized districts. The rate of accidents caused by a vehicle deviating from its lane is higher and the tendency for the accident rate to rise as the radius of curvature declines is more marked than in DID and other urbanized districts (Figure 5). This is result of the fact that in a non-urbanized district, the percentage of two-lane roads is higher and the percentage of roads with a central median is lower than in a DID and other urbanized districts (Table 2, 3).

3.3 Correlation of number of lanes and radius of curvature with the accident rate

The correlation of the radius of curvature with the accident rate was analyzed for road sections with two-lanes (including 3 lanes) and road sections with four or more lanes (Figure 6). The analysis revealed that regardless of the number of lanes, the smaller the radius of curvature, the higher the accident rate. It also clearly shows that at almost all radii of curvature, the accident rate is higher on roads with four or more lanes than on two-lane roads.
Next, the correlation between the radius of curvature and the accident rate was analyzed by number of lanes by type of accident (Figure 7). It revealed that on roads with four or more lanes, the percentage of all accidents that are rear-end collisions is extremely high at more than 50%. This is assumed to be a result of the fact that many sections with four lanes or more are located in DID regions (See Table 2 above). On two-lane roads on the other hand, the accident rate of accidents caused by vehicles deviating from their lanes is higher than it is on roads with four lanes or more. This trend is more marked where the radius of curvature is small (Figure 8). This is assumed to be a result of the fact that because there is more waiting space on roads with four lanes or more, there is a high probability of vehicles stopping in adjoining lanes without leaving the road or entering the oncoming lane. It is also thought to be an impact of the fact that a high percentage of sections of roads with four lanes or more have center medians.

3.4 Correlation of the presence/absence of a center median and the radius of curvature with the accident rate

The correlation of the radius of curvature with the accident rate was analyzed by presence/absence of a center median (Figure 9). And here, even in cases without a center median, cases where there is a dividing line or zebra pattern that is 50cm or wider are included in "with center median." It is assumed that the installation of a center median prevents head-on collisions do not occur so at first the study focused on head-on collisions. It revealed that on all roads, regardless of the radius of curvature, the accident rate is lower with a center median than without a center median. And the smaller the radius of curvature, the greater the gap in the accident rates between roads with a

center median and without a center median. This means that the smaller the radius of curvature, the greater the head-on collision prevention effect of installing a center median.
Next, an analysis was done by roadside situations and by number of lanes (Figure 10). Regardless of the roadside situations and regardless of the radius of curvature, the accident rate is lower with a center median than it is without a center median. On roads with both two lanes and with four lanes or more, regardless of the radius of curvature, the accident rate tends to be lower with a median than without a median.
Looking at the statistics by type of accident on the other hand, reveals that accident rates of vehicle to people collision, crossing collision, and collision while turning right tend to be lower with a center median than without a center median when the radius of curvature is large (Figure 9). This is assumed to be a result of the fact that installing a center median prevents pedestrians from crossing a street outside of pedestrian crosswalks and also prevents drivers from entering and leaving road side facilities (right turns from the main road and right turns from the roadside space).

4. CONSIDERATIONS AND CONCLUSIONS

This research, the analysis of data concerning traffic accidents and road traffic conditions, was carried out so that designers can select road alignments considering the impacts of roadside situations, number of lanes, and the placement of traffic safety facilities in order to design safer roads. It clarified the quantitative correlation of the road alignment, roadside situations, the number of lanes, and the placement of traffic safety facilities with the state of occurrence of traffic accidents. The results can be applied to perform management to reduce traffic accidents through road projects and road operation. For example, it is possible to apply the results presented in this report to predict the safety of a road before it is opened to service or before any accidents have occurred, or to implement advance countermeasures in dangerous sections. It can also be used to select locations to improve the road alignment, install a center median, or to take other traffic safety measures, or to perform an advance evaluation of the effectiveness of their implementation. The results also can also be applied to calculate traffic accident reduction benefits and to design optimum roads considering the cost-benefits ratio.
A study of the results of the analysis has provided the following knowledge. This knowledge is counted on to contribute to safer road design as a check list used to select road alignments.
(1) The results of simply analyzing the radius of curvature – accident rate correlation revealed that as expected, the smaller the radius of curvature, the higher the accident rate. In other words, it has shown that a small radius of curvature should be avoided.
(2) It was observed that if the radius of curvature is higher than a specific value, even if it continues to increase, the accident rate does not decline, and in fact, tends to rise as the radius of curvature nears the linear. But examining the results by type of accident revealed that the accident rate for many kinds of accidents, those caused by a vehicle deviating from its lane in particular, declines as the radius of curvature increases. This means that the radius of curvature should be as large as possible to reduce physical impacts (centrifugal force) to prevent lane deviations.
(3) Analysis revealed that the larger the radius of curvature, the higher the rear-end collision accident rate. It is assumed that rear-end collisions are not closely related to the physical impact of the plane curve. This means that regardless of the radius of curvature, the rear-end collision accident rate ought to be almost constant. Despite this, the rise in the rear-end collision accident rate may be a result of a decline of drivers' attentiveness because the more nearly linear the road alignment, the safer they feel. Where the radius of curvature is large, measures should also be taken to stimulate the attentiveness of drivers.
(4) Analysis revealed that the rate of accidents caused by vehicles deviating from their lane is higher in non-urbanized districts than in DID and other urbanized districts. And the tendency for the accident rate to be higher when the radius of curvature is smaller is more pronounced. It is, therefore, assumed that the radius of curvature in non-urbanized districts should be set as large as possible.
(5) The analysis revealed that in DID and in other urbanized districts, the percentage of accidents that are rear-end collisions is high. This is assumed to be a result of the fact that there are many facilities that vehicles enter and leave along roads in DID and other urbanized districts, and that vehicles decelerate suddenly to avoid colliding with vehicles entering and leaving these facilities. Another reason is that signboards of roadside facilities reduce the attentiveness of drivers to their driving. This means that under the effects of the high rear-end collision accident rate, if the radius of curvature exceeds a stipulated value, the larger the radius of curvature, the higher the accident rate. As stated in (3), if the radius of curvature is large, measures to stimulate the attentiveness of drivers should be implemented at the same time. The accident rate is lowest near a radius of curvature between 400m and 500m in DID (in other urban districts, 400m to 1,000m). It is assumed that the radius of curvature in DID and other urban districts might be better to set at such values.

(6) On two-lane roads, the accident rate for accidents caused by lane deviation is higher than it is on roads with four or more lanes, and the smaller the radius of curvature, the greater this difference. This is assumed to be a result of the fact that because there is more waiting space for vehicles on roads with four or more lands, vehicles do not leave the road or deviate into the oncoming lane. When a small radius of curvature is unavoidable, an effective countermeasure might be increasing the number of lanes near the curve. An effective solution might be to provide shoulders etc. wide enough that the number of lanes cannot be increased.
(7) Analysis revealed that regardless of the radius of curvature, the head-on collision accident rate is lower where there is a center median than where there is no center median. The smaller the radius of curvature in particular, the larger the gap between the accidents rate with a center median and without a center median. This means that the smaller the radius of curvature, the greater the effectiveness of constructing a center median.

In this study, we analyzed the correlation between roadway alignment and accident rates. A more detailed study of the correlation between roadway alignment and accident severity should be undertaken in future. Also the difference between daytime crashes and nighttime crashes should be undertaken in future.

LIST OF TABLES AND FIGURES

Table 1 Definition of Roadside Situations

Roadside situations	Definitions
DID	Region in cities, wards, towns, and villages where there are adjoining surveyed districts with high population density (about 4,000 people/km^2 or more) and with total population of 5,000 people or more.
Other urbanized districts	Region with continuous occupied buildings on both sides of the roads, forming an urbanized district.
Non-urbanized districts	Region with 'flat land' or with 'mountainous land'. Flat land is the region without continuous occupied buildings and with gently graded roads. Mountainous land is the region including mountains, hills, and foothills.

Table 2 Number of the sample by roadside situation by the number of the lane

	2 lanes	4 or more lanes	Percentage of two-lane sections	Total
DID	2,279	3,248	41.2%	5,527
Other urbanized districts	3,523	685	83.7%	4,208
Non-urbanized districts	24,251	1,658	93.6%	25,909

Table 3 Number of the sample by roadside situation by with/without center median

	With center median	without center median	Persentage with center	Total
DID	2,460	3,067	44.5%	5,527
Other urbanized districts	583	3,625	13.9%	4,208
Non-urbanized districts	1,530	24,379	5.9%	25,909

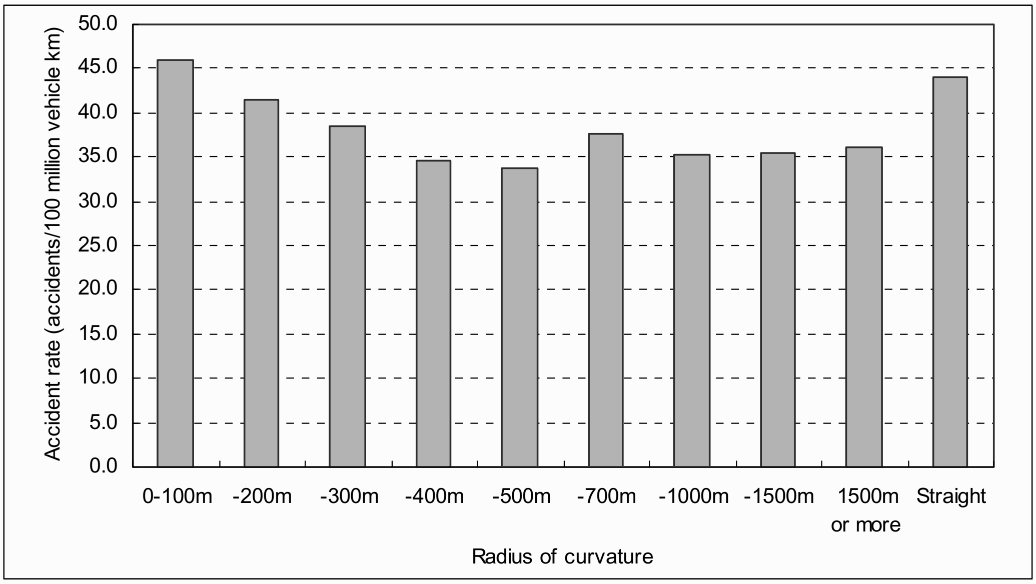

Figure 1 Correlation of radius of curvature with accident rates.

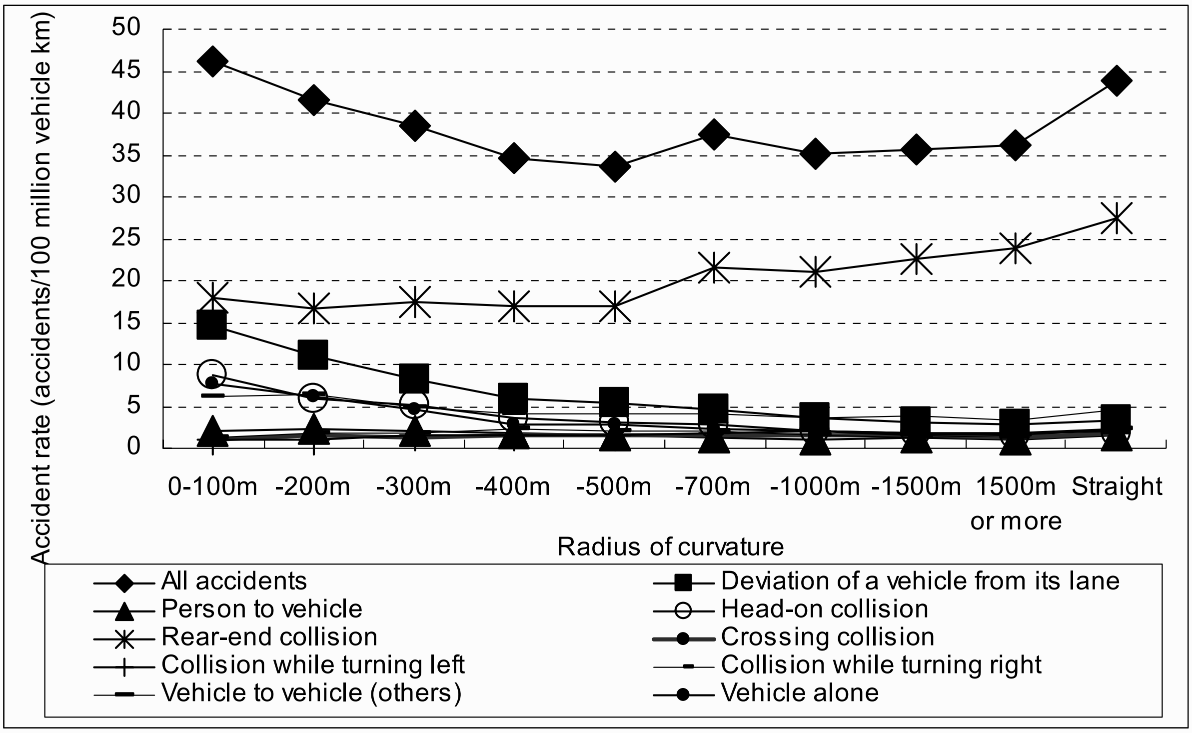

Figure 2 Correlation of radius of curvature with accident rates by type of accident.

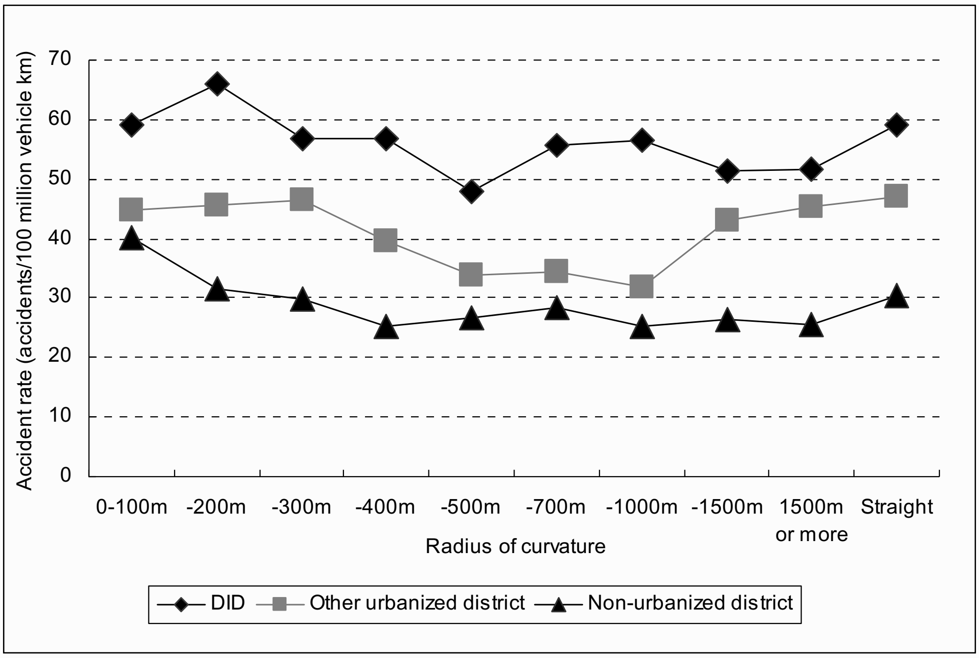

Figure 3 Correlation of radius of curvature with accident rates by roadside situation.

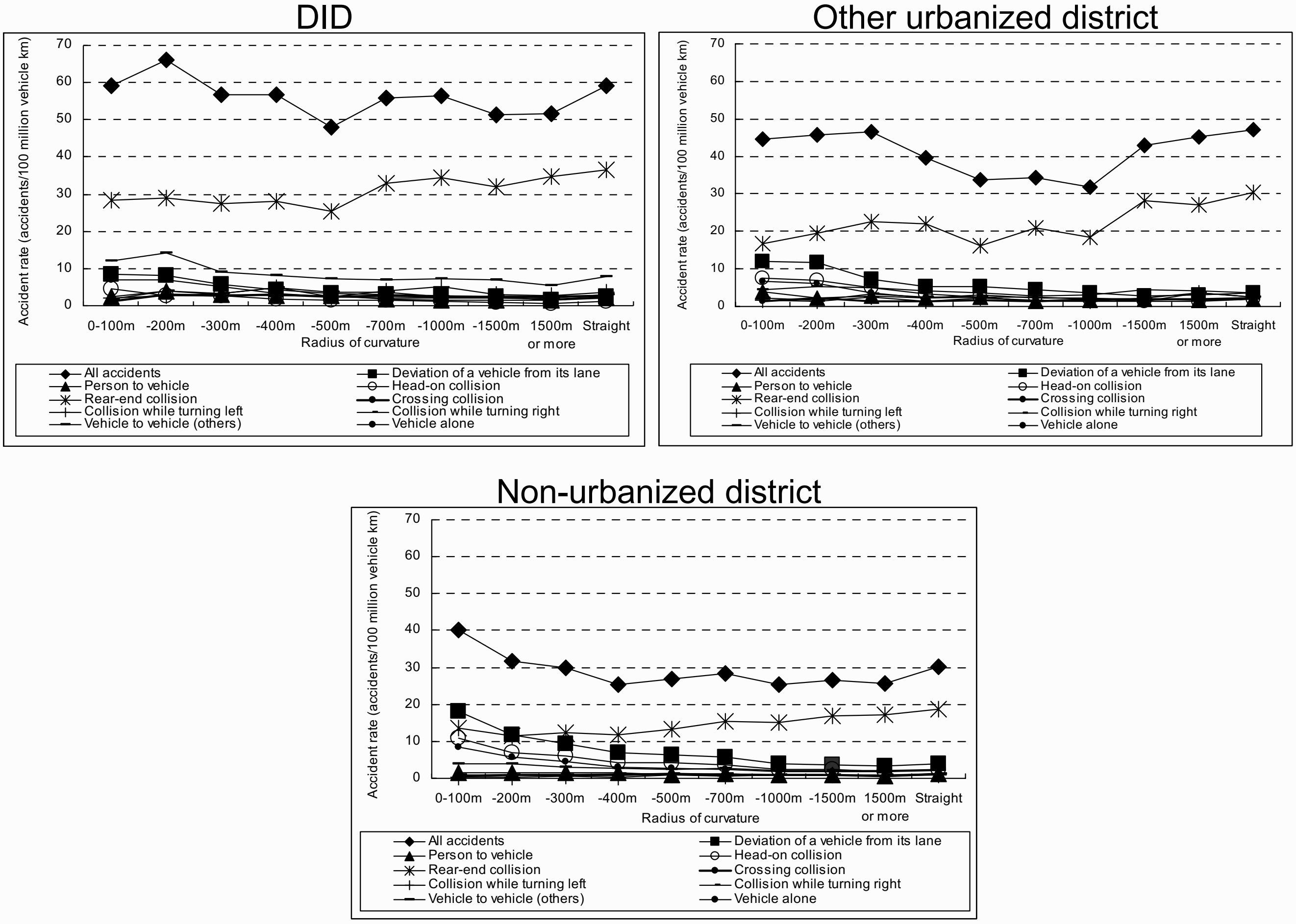

Figure 4 Correlation of radius of curvature with accident rates by roadside situation by type of accident.

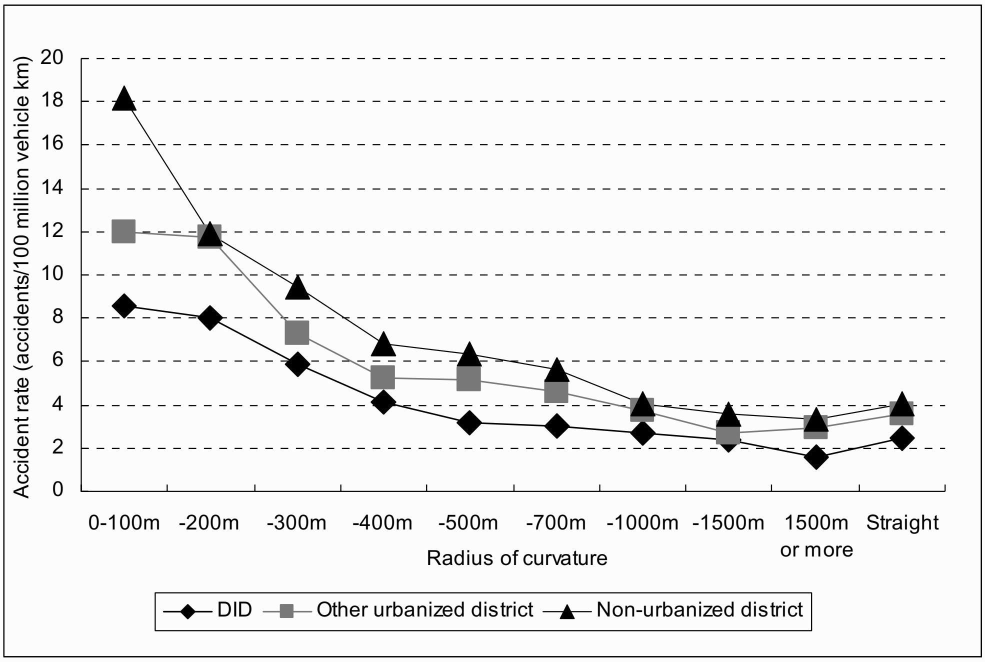

Figure 5 Correlation of radius of curvature with accident rates by roadside situation (Deviation of the vehicle from its lane).

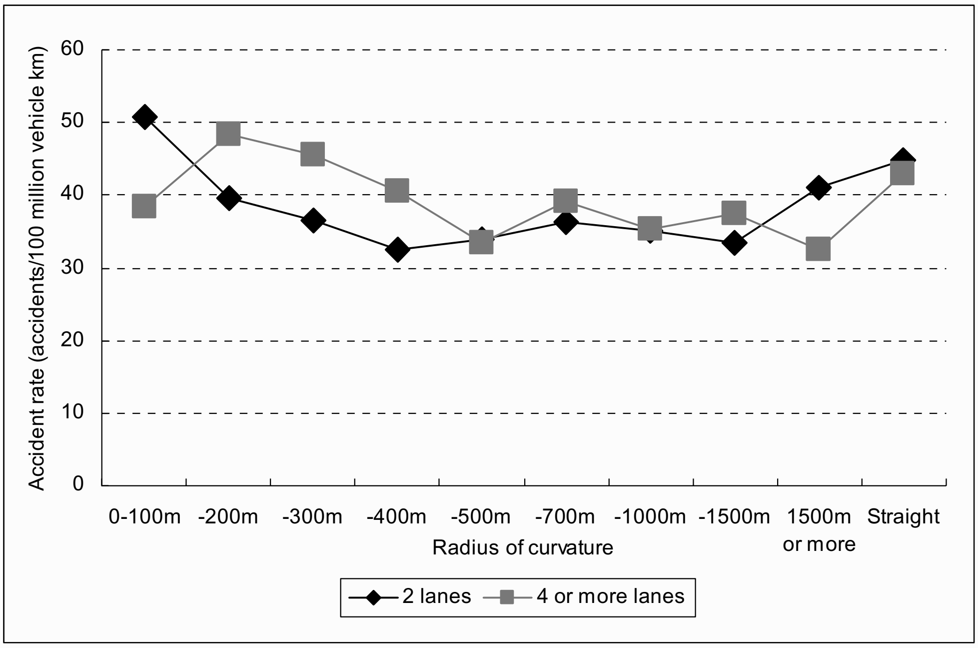

Figure 6 Correlation of radius of curvature with accident rates by number of lanes.

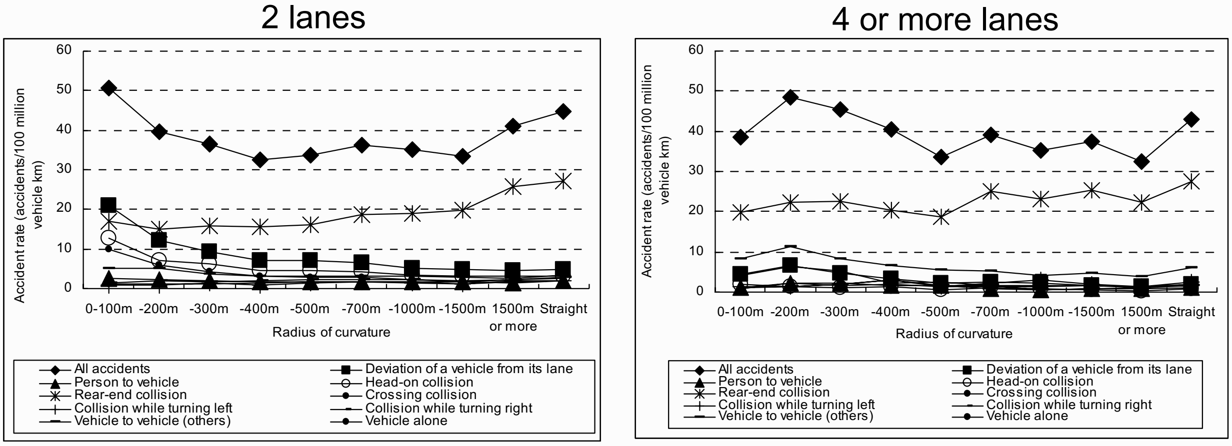

Figure 7 Correlation of radius of curvature with accident rates by number of lanes by type of accident.

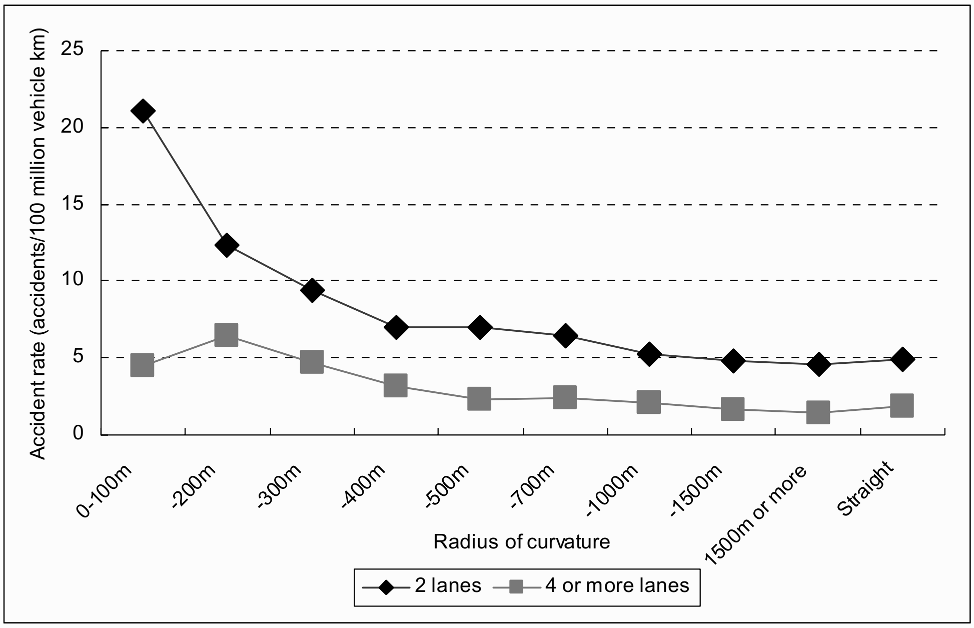

Figure 8 Correlation between radius of curvature and accident rates by number of lanes, considering only accidents involving deviation of the vehicle from its lane.

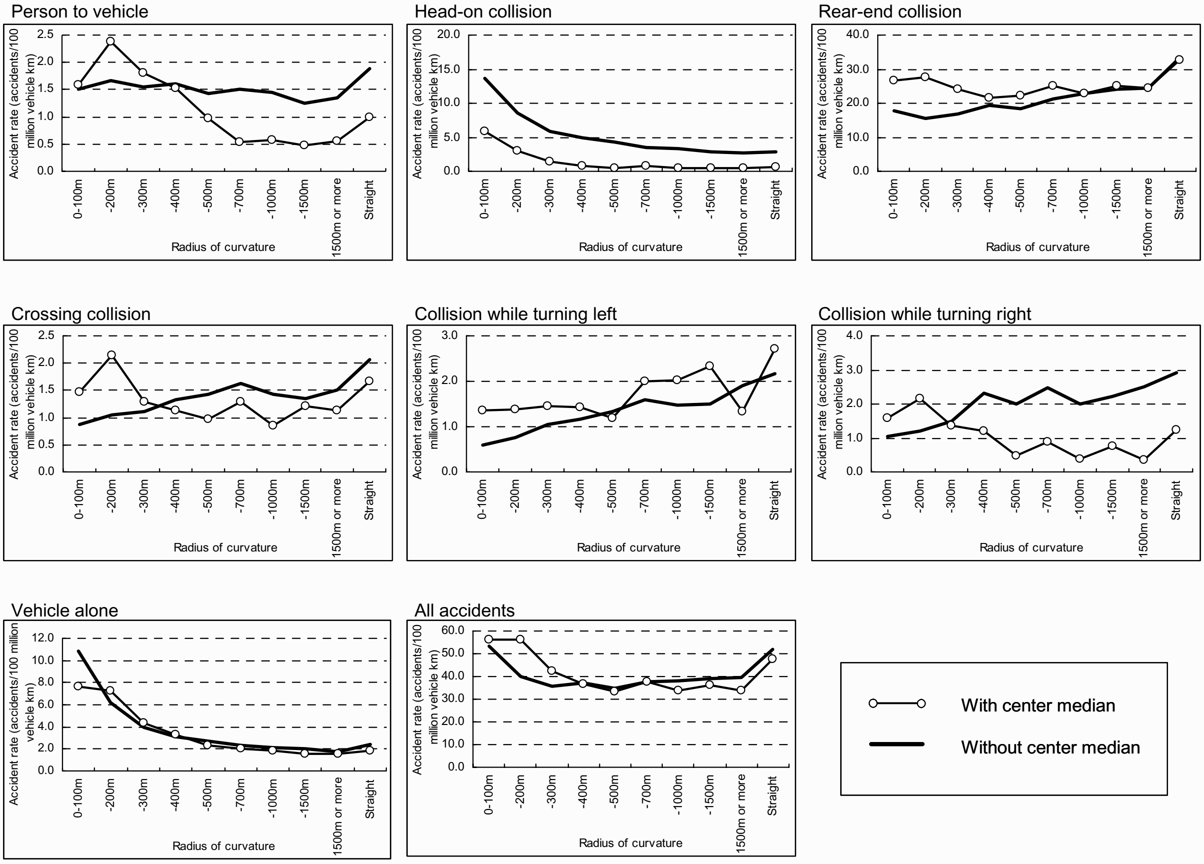

Figure 9 Correlation of radius of curvature with accident rates by with/without center median by type of accident.

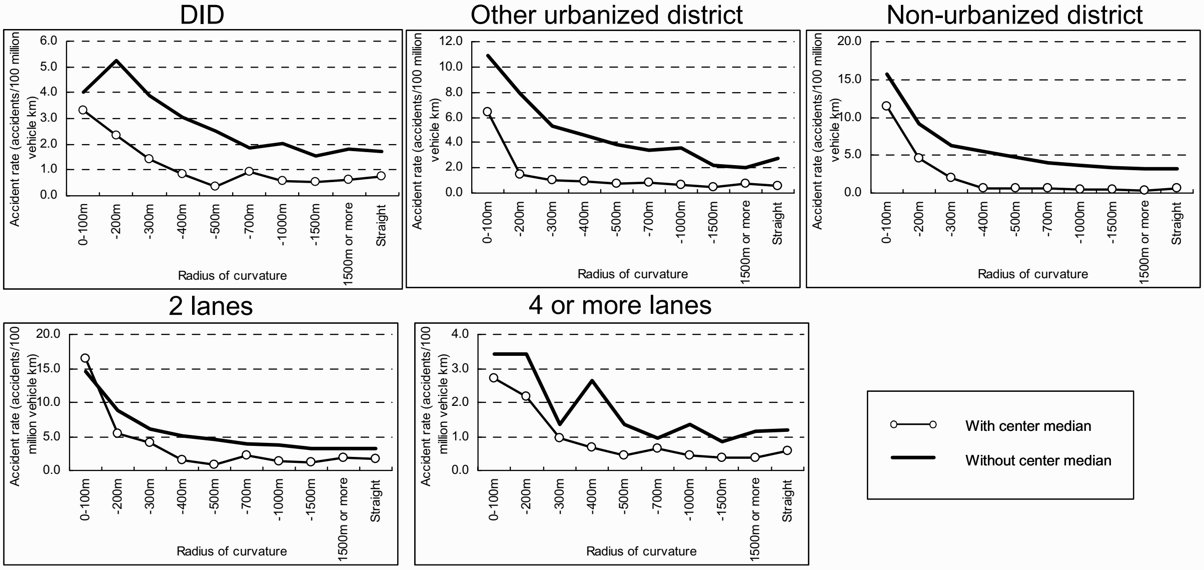

Figure 10 Correlation of radius of curvature with accident rates by with/without center median by roadside situation / the number of the lane (head-on collision).