A Study on the Effects of Sight Distance on the Driven Speed of Vehicles

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林道における視距が車両速度に及ぼす影響

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Abstract: The first half of this study shows the quantification analyses of the general design factors of roads, while the secod half deals with the experiments made on these analyses. The analyses were made on the relationship between the geometrical factors of forest roads and the driven speed of vehicles, by using qualitative factors as well as quantitative ones. As a result, it was found that there exist a large partial correlation coefficient between the sight distance, which is a kind of multi-dimensional fnuction, and the driven speed of vehicles. The reliability of prediction on the vehicles' driven speed may be high if it is based on sight distance. The longer the sight distance, the higher the driven speed of vehicles. It was found that a curve mirrors installed at an intersecting point of curve is effective on the sight distance. The sight distance increased by 13 ± 10 % for small-sized vehicles, 18 ± 8 % for medium-sized vehicles, and 6 ± 3 % for large-sized vehicles.

Introduction

There have been many studies done to determine the relationship between the group on mechanical factors of forest roads and the driven speed of vehicles that run thereon. However, the correlation coefficient as found on those studies have not been high enough[1). The values of the correlation coefficient might have been low because the past studies took only those quantitative factors into condideration. None of them have considered the qualitative factors.

In this study the author tries to include various groups of factors, geometrical design, of vehicles' performance, environment, and ergonomics, all including those elements of qualitative nature.

The driven speed of vehicles changes subject to various factors such as the geometrical design of roads, the capacity of vehicles, human sensitivity or terrainous environment. However, the group of human factors does not function effectively by themseves. Very often they function only when interacted with other factors. The main human factors herein indicated include those of mental nature and moral nature of human being. Related closely to these two factors is road alignment. The effect of road alignment becomes more con spicuous when one cannot see or tell the state of alignment beyond the curve in front of him.

One can speak of this effect in terms of sight distance, too. Considering the sight distance as a criterion in measuring the vehicles' driven speed, such factors as the radius of curve, curve length, drivers' mental state, or their law-abiding mind may be included among the parts of the sight distance. The sight distance therefore should be regarded as a multidimensional factor.

In an effort to clarify the function of the sight distance that is played in determining the vihicles' driven speed, an experiment was concuted to view the behavior of traffic on existing forest roads. It was expected to clarify how the driven speed varied according to the quantitative or qualitative changes in the multi-dimensional factor, the sight distance.

Method of Measurment

From the result of the experiments made on how geometric design factors of existing forest roads affect the driven speed of vehicles, it is possible to draw their own characteristic features, but it is rather difficult to ascertain the effect of geometrical design factors. In order to treat this problem properly, it is necessary to design experiments orthogonally and collect as many data from as many forest roads as possible.

The data compiled here have also been used in the study of trffic on the forest roads[2]. The driven speed of vehicles was measured at four points of curve: the first one at a point 20 mteters before point BC, the second at point BC, the third at point EC and the forth at 20 meters after point EC.

The measurements of driven speed were taken by an instrument of traffic counter with a built-in time recorder. Other groups of factors, such as the factors of geometrical design, the human factors, and environmental factors were each measured by people in charge of taking the respective measurements.

Method of Analyses

Because it was necessary to measure the qualitative factors in addition to the quantitative factors, the means of multivariate analyses by quantification method was adopted. The quantification method of this paper (in which the outside criteria is used,) is similar to that of socalled Hayashi's Quantification Scaling Type 1[3].

Classiffication of Items and Categories: The data described above are classified as follows: The outside criterion (Y) is the driven speed declined (V), that is, the difference in speed (40−V) km/h between the design speed (40 km/h) of the road and the actual driven speed (V km/h) of vehicles observed on the road[4].

The explanatory variables of the outside criterion (Y) and their levels were classified into 4 groups as given in Table 1. Each group was divided into several items, which were further sub-dicided into 2 ～ 6 categories. The intra-category borderlines were determined after calculations were repeated several times until the correlation coefficient and the contributed ratio came to show the values reliable enough for use[5].

The classifications thus finally arrived at are given in Table 1.

Table 1 *The classification of items and categories*

GROUP	ITEM	CATEGORY	COMMENT
The factors of geometrical design	Radius of curve	Small Medium 1 Medium 2 Large Very large	R=Less than 10 m R=10 m to 20 m R=21 m to 30 m R=31 m to 40 m 41 m and over
	Curve length	Short Medium Long	Cl=Less than 10 m Cl=10 m to 20 m Cl=21 m and over
	Curve ratio	Small Medium Large Very large Super large	Less than 1.5 1.51 to 2.00 2.01 to 2.50 2.51 to 3.00 3.01 and over
	Gradient	Easy/Favorable Ordinary/Favorable Steep/Favorable Easy/Adverse Ordinary/Adverse Steep/Adverse	Less than 2.9 % 3.0 % to 7.0 % 7.1 % and over Less than 2.9 % 3.0 % to 7.0 % 7.1 % and over
	Width	Narrow Medium Wide	Less than 3.59 m 3.60 m to 4.00 m 4.01 m and over
	Side ditch	No Exist	
	Sight distance	Very short Short Little short Medium Little long Long	Less than 10 m 11 m to 15 m 16 m to 20 m 21 m to 30 m 31 m to 40 m 41 m and over
	Curve frequency	Few Medium Many	Less than 2 3 and 4 Greater than 5
	Direction of curve	In-curve Out-curve S-curve Straight	
The factors of the environments	Road edge	Clearness Standard Obscurity	Clearness Standard Obscurity
	Road side	High wall without gurd High wall with gurd Ordinary Without reliable edge	
	Road surface	Smooth Medium Rough	Vibro. acc. =less than 0. 5g Vibro. acc. =0.51 to 2.0 g Greater than 2.1 g
	Brightness on the surface	Brightnss Darkness	
	Traffic density	Very few Medium Many	1.0 vehicle per an hour and under 1.0±1.0 vehicle/30 minutes 1.0 vehicle/5 minutes and over
	Forest stand	Country forest Mountain forest Remote mount. for.	Less than 45 min. from market 46 min. to 90 min. from market 91 min. and over

GROUP	ITEM	CATEGORY	COMMENT
Performances factors	Kind of vehicles	Very small vehicle Small size vehicle Medium size 1 Medium size 2 Large size track 1 Large size track 2	Keiyon Passenger car Van type & coach type vehicle Medium size track-empty- Large size track-empty- Large size track-loaded-
	New or used	New car Used car Old car	As good as new Slightly scrap
Personal factors	Age	Less than 25 years 26 to 35 years 36 years and over	
	Personality	Gently Ordinary rough	
	Sex	Male Female	
	Traffic purpus	Man-transportations Timber-transport. Others	

Result of Analyses and Discussions

The reliability of the analyses: The reliability of the over-all analyses may be determined by multiple correlation coefficient ρ, which was arrived at 0.8764 given in Table 3. The reliability should, therefore, be regarded high. The quantitative comparisons between the observed values and the estimated values are given in Table 2.

Table 2 *The comparison between the observation and the estimation quantification*

	Mean	Standard dev.
Observed value (Y)	7.317	1.23422
Estimated value (X)	7.3098	1.18575
Correlation coefficient	0.87371	
Regression epuation	$Y = 0.99985\,X + 0.00076$ $X = 0.77812\,Y + 1.61830$	

The contributed ratio of each item: The multiple correlation coefficient ρ between the total 22 items/77 categories and the outside criterion (Y) is 0.8764. This value is reliably high. The partial correlation coefficient of each item is given in Table 3. The contributed ratio between each item and outside criterion can be judged from the partial correlation coefficient and the range.

In this study, the partial correlation coefficient is used because the observed data were sufficient enough in number compared with the number of categories and the characteristics of the two approximately agreed to each other[6].

It will be recognized in Table 3 that such items as kind of vehicles, sight distance, lon-

Table 3 *The list of partial correlations and the multiple correlation of the multidimensional factor analysis of the geometrical design of mountainous forest roads*

Variable factors	Partial corr. coeff.
Radius of curve	0.2810
Curve length	0.2803
Curve ratio	0.3459
Longitudinal grade	0.4000
Width of road surface	0.3200
Side ditch	0.1425
Sight distance	0.4118
Curve frequency	0.2916
Direction of curve	0.1573
Road edge	0.1009
Road side	0.1880
Road surface	0.3607
Brightness on the surface	0.0602
Traffic density	0.1023
Forest stand	0.2731
Kind of vehicles	0.4224
New or old car	0.1366
Driver's age	0.2017
Career experience	0.2005
Personality	0.2789
Sex distinction	0.1428
Traffic purpus	0.1889
Multiple correlation coefficient 0.8764	

gitudinal grade, road surface, curve ratio, width, curve frequency and radius of curve exercise heavy influence on the speed of vehicles. Next influentical items are curve length, personality of drivers, forest stand, drivers's age, and their career experience.

In the following, the two items (kind of vehicles, sight distance) that showned high partial correlation coefficient value are selected to show further calculations as stepwise.

First, all the remaining items were input to get the multiple correlation coefficient. It was 0.6667. As a next step those 2 items were included for multiple correlation coefficient. The result was 0.8764 as indicated above. This means that these two important factors alone may be sufficient enough to explain the influence.

The contributed ratio of categories : It is seem from Table 3 that the four factors (kind of vehicles, sight distance, longitudinal grade and road surface) had the highest contributed ratios. Then under what state of condition do these four factors exercise the strongest infiuence ?

It is not impossible to speculate on a contributed ratio from the deviation value of the categories. From those categories that have the partial correlation coefficient at the significant level of 1 %, Figure 1 was obtained. Because of the fact arrived at from this study that the partial correlation coefficient of all items showed positive values, it may be said

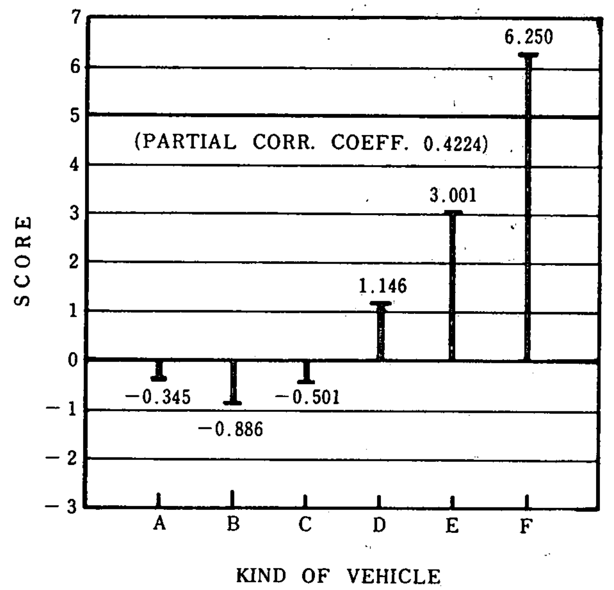


Fig. 1 (a) Score of each category about "the kind of vehicle"
Note ; Category A : Very small car (Keiyon)
Category B : Small sized (Passenger car)
Category C : Van & coach type car
Category D : Medium sized track
Category E : Empty large sized track
Category F : Loaded large sized track

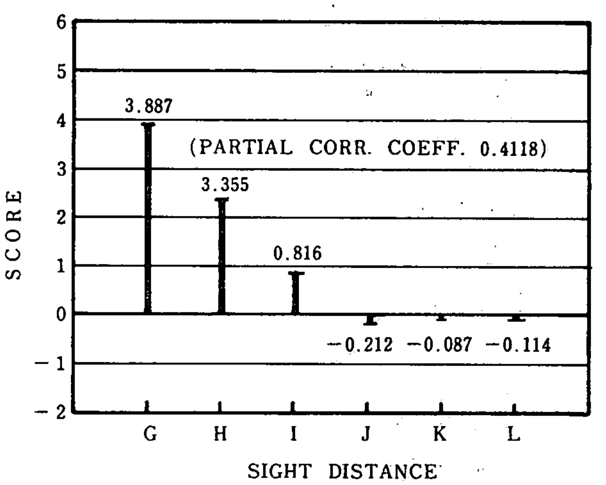
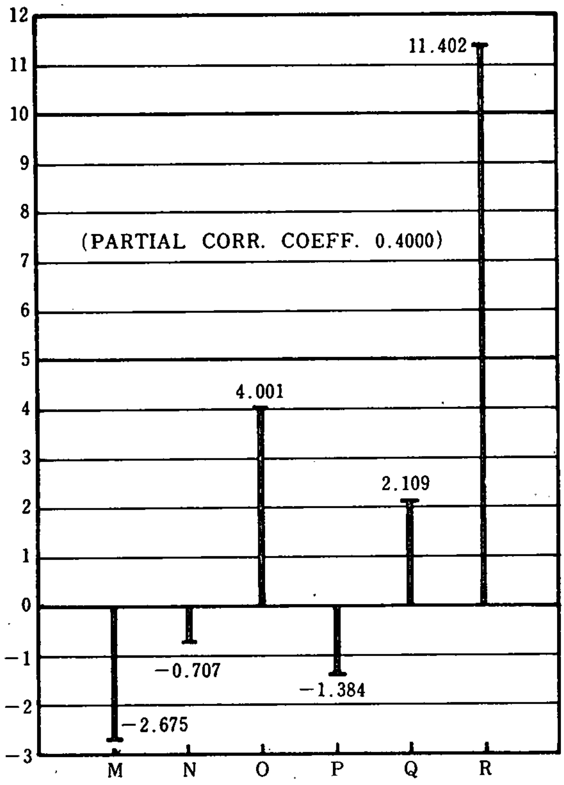


Fig. 1 (b) Score of each category about "the sight distacne" on the curve
Note ; Category G : Very short
Category H : Short
Category I : Little short
Category J : Medium
Category K : Little long
Category L : Long



.Fig. 1 (c) Score of each category about "longitudinal grade".
Note ; Category M : Easy favourable grade
Category N : Ordinary favourable grade
Category O : Steep favourable grade
Category P : Easy adverse grade
Category Q : Ordinary adverse grade
Category R : Steep adverse grade

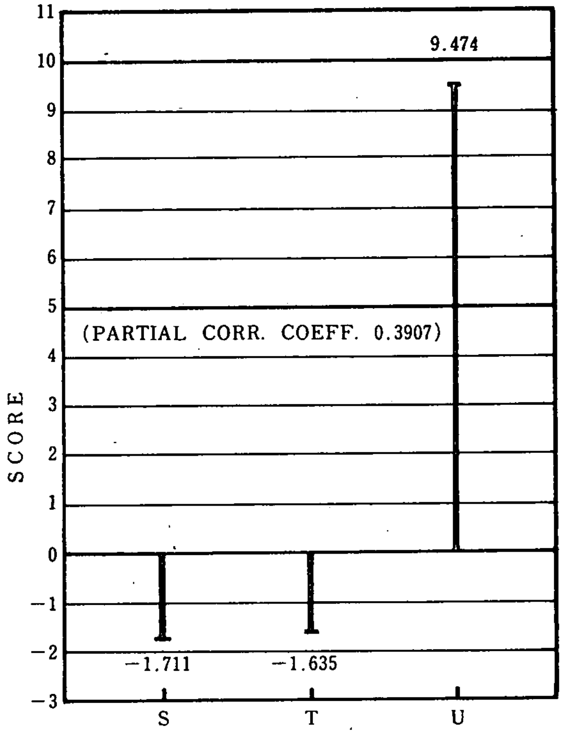


Fig. 1 (d) Score of each category about "the roughness of road surfaces".
Note ; Category S : Smooth
Category T : Ordinary
Category U : Rough

that the influence of those categories that holds the highest score values exercise large influence. For example, the category "loaded large sized truck" under item "kind of vehicle" came to be known as the factor that caused a slow-down of speed. Likewise, " less than 20 meters" under "sight distance", "greater than 7 % in case of adverse grade" under "grade", and "rough" under "road surface" became the influencial factors.

The remaining two thirds of the items/categories had the partial correlation coefficient at a signigicant level of 5 %. No further effort shall be needed to explain other items/categories because they had low partial correlation coefficient, and their significant levels are low also.

In estimating the speed of vehicles, "kind of vehicles" is a constant of factor[7], and therefore should not be considered a criterion in estimating the vehicles' speed. Therefore, sight distance was adopted in its place. The factor "sight distance" contains an element of alignment factor and of ergonomic factor, and therefore, is a multi-functional factor, and may be a factor more useful than curve ratio (K)[2] and travel time factor (B)[8] which has been a conventional parameter in evaluating the geometrical design of roads.

Experiment

As described above, it is clear that the sight distance, especially when it is short, have a great influence on the driven speed of vehicles. Efforts are therefore made to empirically observe the relationship between the sight distance and the vehicles speed on forest roads. The results are shown in Figure 2. The date compiled here were taken in a road having the longitudinal grade of $0 \sim \pm 3\%$.

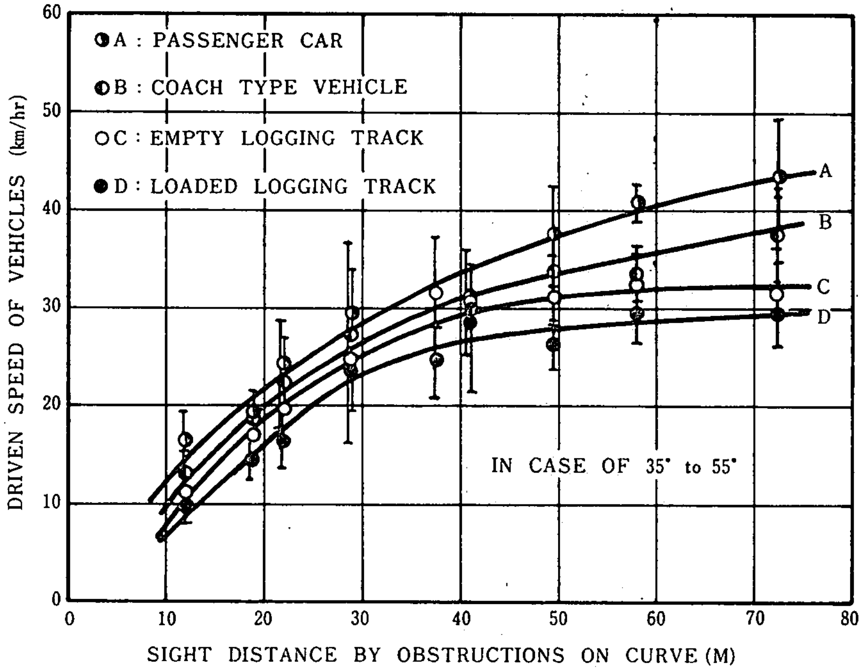


Fig. 2 The relation between the sight distance on the curve and driven speed of vehicles.

Short sight distance exists only in a land formation having a steep side slope and a sharp curve. In such area, it is not possible to scrape out the inside of the out-curve and provide a visivility berm to improve sight distance. Nor is it spossible in in-curve area to fell out standing trees at the road side for better sight distance, because it has relation to a reduction of productivity in forest land.

Here is a way to improve sight distance. It is to set up a curve mirror. A study therefore, was made to see how it improved the sight distance and how it affected the speed of vehicles.

The experiment was conducted in the same place under the same condition as those mentioned above. Ideally, it is best to install a curve mirror at an intersecting point of curve to obtain the best sight distance. However, it may not produce the best result because the direction of vision is different from that of the vehicle when the external secant of the curve is very long (the curve is sharp). Besides, more often than not, the lane formation prevents a curve mirror to be installed at a intersecting point of curve.

Actually, more mirrors are being installed at a road shoulder, and therefore, the experiments were conducted under such set ups.

Sight distance may be theoretically calculated in the following formula when a mirror was installed at road shoulder:

$$SD' \geqq 2\left\{(TL)^2 + \left(ES - \frac{B}{2}\right)^2 - 2TL\left(ES - \frac{B}{2}\right)\cos\frac{180-\theta}{2}\right\}$$

where SD' : Sight distance
TL : Tangent length
ES : External secant
B : Width of surface
θ : Intersection angle

However, the sight distance reflected in the mirror and so recognized by a driver in the running vehicle for 2~3 seconds may not be as long as the theoretical calculation tells us.

The experiments with the curve mirror (600 mm in diameter) have produced the results shown in Figure 3.

The speed observed in this experiment was plotted and overlapped with Figure 2 for comparison. The results obtained are shown in Figure 4 (a), (b) and (c).

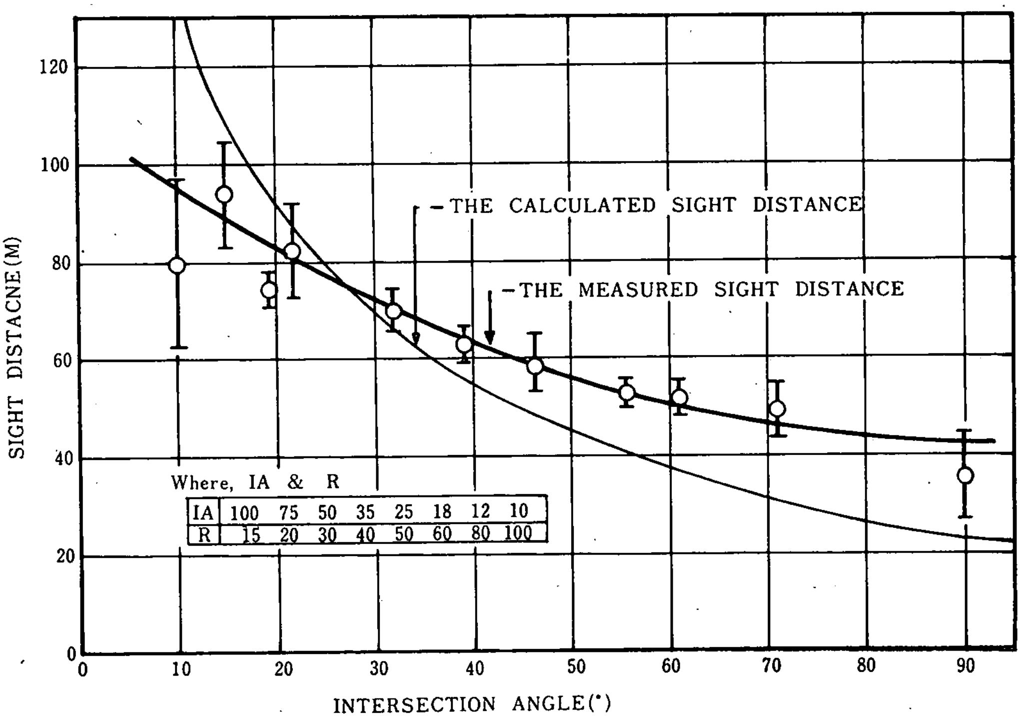


Fig. 3 Measured value of improved sight distance——to set a curve mirror.

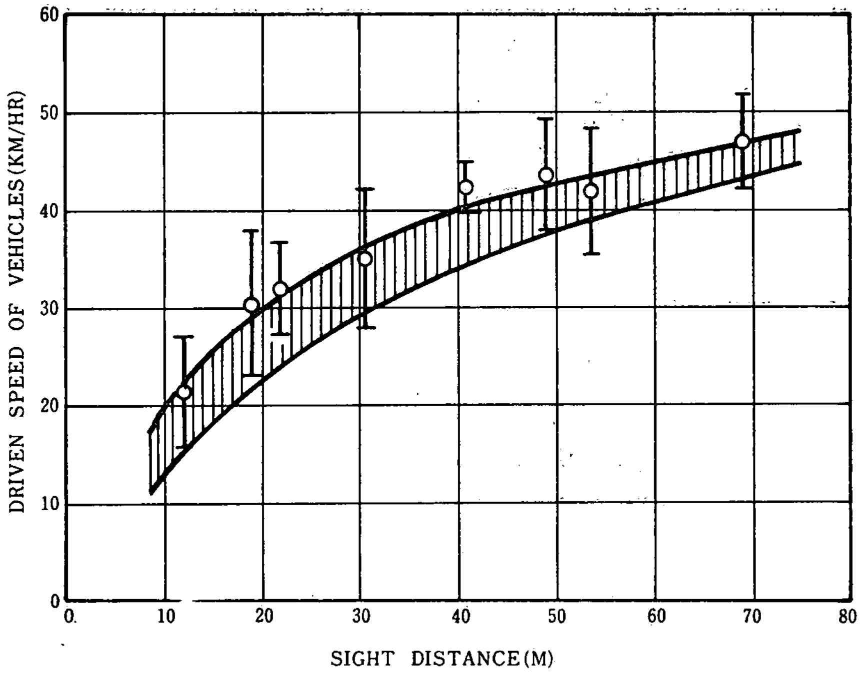


Fig. 4 (a) An effect of the curve mirror on vehicle speeds
——In case of the passenger car——.

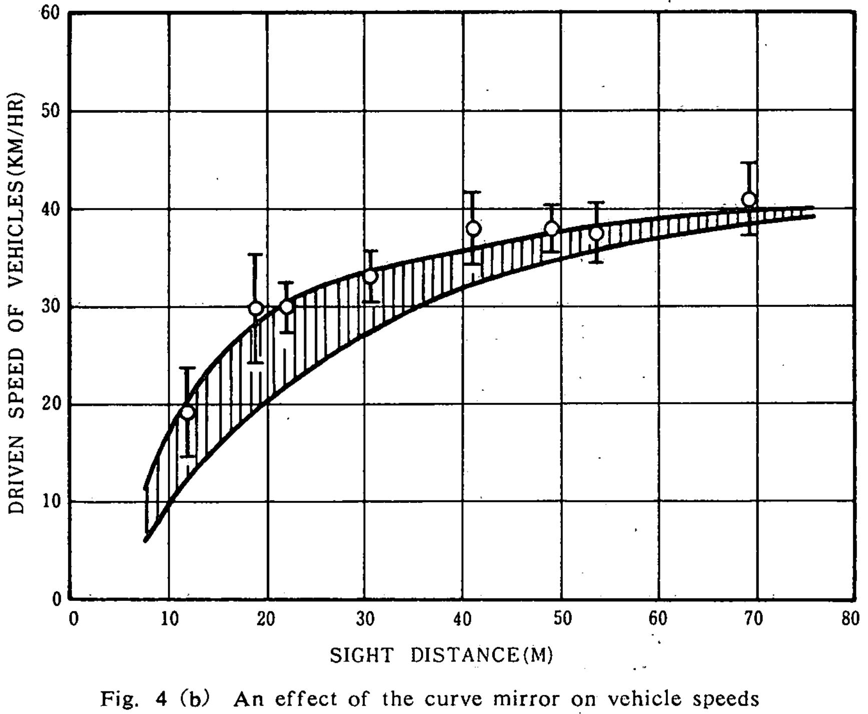


Fig. 4 (b) An effect of the curve mirror on vehicle speeds
——In case of the coach type car (medium sized car)——.

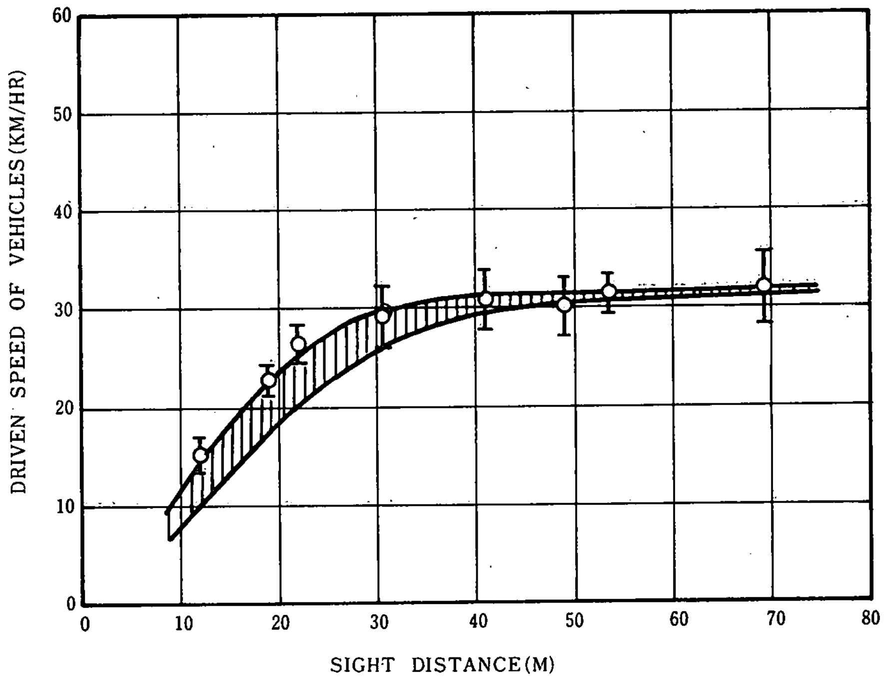


Fig. 4 (c) An effect of the curve mirror on vehicle speeds
——In case of the empty logging track——.

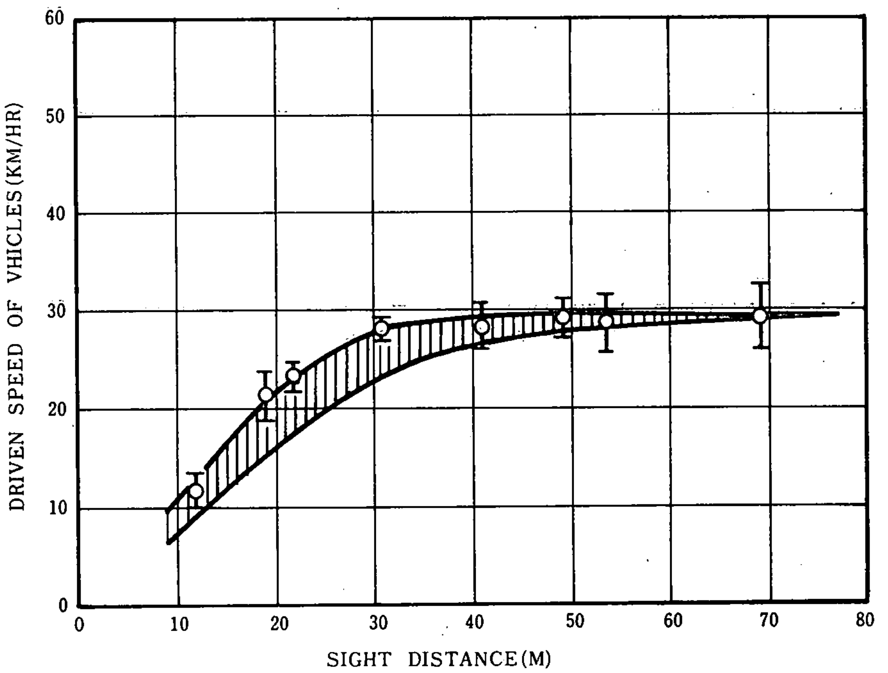


Fig. 4 (d) An effect of the curve mirror on vehicle speeds
——In case of the loaded logging track——.

Conclusion

With introduction quaiitative factors into consideration, it became clear that sight distance had a great deal to do in determining the vehicles speed. In forest roads, the sight distance is likely to be short. There may be a few ways to make the sight distance long, but installment of curve mirrors may be the most effective and reasonable way of all.

The curve mirror, however, does not exercise the influence on all vehicles to the equal degree. When a mirror is installed, small sized vehicles increase their driven speed by 13 ±10 %, middle sized vehicles by 18 ±8 %, and large sized vehicles by 6±3 %. So the effect of curve mirrors should not be underestimated. The driven speed deviation in large sized vehicles is small perhaps because the speed of large sized vehicles has already been controlled to some extent by other factors.

In this study the largest influence is seen in medium sized vehicles. However, other types of vehicles may also be benefited by the mirror if further consideration is given to the diameter of mirror, the cuvature of the mirror surface, the height and the position of the mirror.

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