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Evaluation of the visibility distance with the Istram program on third-class roads with a high accident rate

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***Abstract*– In Peru there are many roads where accidents occur due to their inadequate geometric design. The traffic accidents with the most incidents are of the side collision or collision type with a percentage of 42.73%, and distraction with 20.19% [1]. This shows that it is necessary to carry out a redesign on this road that seeks to reduce the percentage of accidents in the area.**

For the case study, a section of a 3km highway located in Santiago de Chuco, north of the city of Lima, was used. Thanks to the photogrammetric record of the current state of the road, sectors with geometric deficiencies were identified, such as visibility distance and safety in terms of precariousness in the use of signaling. Likewise, the evaluation carried out in the stopping and overtaking visibility distance concludes that with a constant speed of 30 km/h there are stretchs or sections that do not meet the necessary distance for its route.

Keywords— photogrammetry, visibility distance, roads, accidents.

I. Introduction

Human and vehicular factors play an influential role in road accidents. To carry out possible maneuvers that driving entails, the pilot must take into account a minimum visibility distance at all times. The different actions inherent to driving, such as stopping the vehicle, going around an obstacle, overtaking cars in the middle of the road or joining the road, require a certain amount of space so that they can be carried out safely and there is no risk of accidents. For this reason, various studies have been developed in order to provide adequate road safety methods by modifying the geometric design of the road.

One study analyzed the geometric design of highways by vehicle type, and consistency models based on vehicle categories were developed for mixed traffic environments on two-lane rural highways in mountainous areas; to minimize the occurrence of unforeseen events when users drive along the road.

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[2]. Similarly, another article refers to decreasing the number of annual deaths and injuries occurring in Iran where Reverse Horizontal Curves (RHC) are found between road points combined with steep longitudinal slopes, especially on mountain routes [3]. Another study succeeded in determining the minimum radius required for RHCs on the highway based on vehicle stability using a dynamic model to simulate truck behavior in different alignments. The results showed that an increase in the minimum radius requirement for RHC is needed to maintain driver comfort levels and avoid potential rollovers [4]. In their research, Garcia et al. wants to solve road safety, since the effect of truck squads causes a reduction in visibility on horizontal curves [5]. In another study, they defend the need for more research on how the geometry of roads could be improved to allow truck traffic safely [6]. Other authors mention the challenge of designing for different levels of drivers, characteristics and conditions of vehicles and roads.

They also indicate that deterministic methods have two main drawbacks: first, design parameters, such as perception and braking reaction time (PRT) and operating speed, are probabilistic in nature. Second, in some cases the designer may need to deviate from the standards due to some limitations. The goal of applying reliability theory to geometric highway design is to establish and promote a more consistent and reliable design process [4].

On the other hand, the authors Hamilton et al. explain that while design consistency has safety implications and is intuitively associated with highway run-off accidents, the authors are aware of only a few studies that have attempted to link measures of design consistency to safety performance [7]. Likewise, they indicate a policy on the geometric design of highways and streets of AASHTO, sixth edition, provides design criteria for horizontal curved elements based on a point mass model [8].

This article seeks to develop a precise analysis of the visibility distance both when stopping and overtaking, taking photogrammetric data, visiting the place and applying tools such as Istram. Because the reality of the road, and especially its environment, is complex. For this reason, the analytical procedures developed for the study of visibility distance are not effective. In addition, there is vegetation on the borders that obstructs the driver's visual field.

II. Methods and Materials

A first study has been carried out on an interprovincial highway located in the north of Peru, approximately 3 kilometers long (Orthomosaic of Shorey highway) (Figure 1) and plan view of the road section (Figure 2). This section of road has been considered due to its sinuous shape and the pronounced curves that it presents along the road, achieving as its main objective to evaluate the visibility distance of the vehicles.

Fig. 1. Orthomosaic of the Santiago de Chuco-Shorey highway.

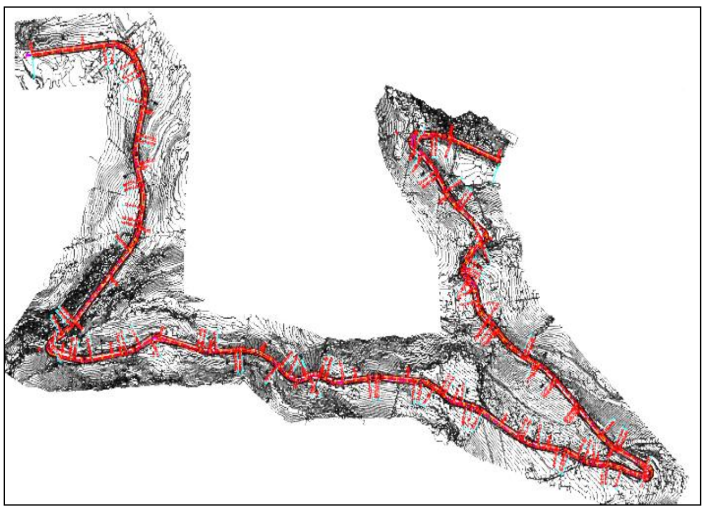

Fig. 2. Section of highway Santiago de Chuco-Shorey

A tool has been implemented in ISTRAM ISPOL for the calculation, analysis and registration of visibility distances of trajectories of vehicles on roads and the use of photogrammetry in the field. To access the use of the visibility tool in Istram, you must load the Peru library, within ELEVATION- UTILITIES-VISIBILITY (Figure 3).

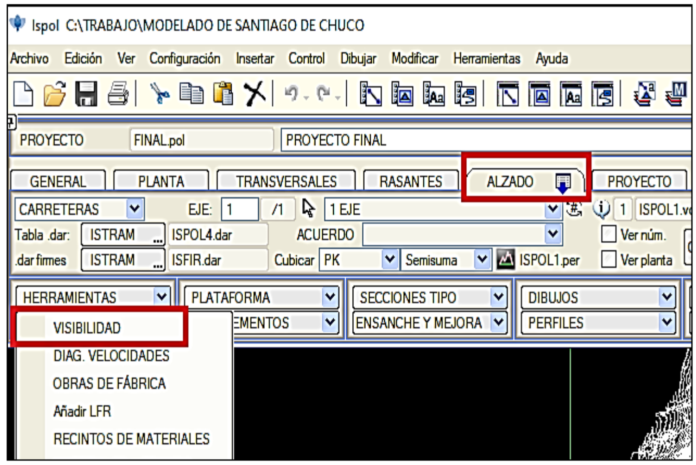

Fig. 3. Visibility distance in the Istram tool

This visibility tool is integrated into Istram as an add-in, and can be added as a button to any toolbar. The aforementioned tool evaluates for the different points located on the trajectory if they are seen from the location where the vehicle is. In principle, no changes should be made to the interface if only one speed is used; otherwise, the study must be applied for each section, placing the effective speed and the Initial and final Pks.

The methods used for development are those applied in the Peruvian Geometric Design Manual 2018 (DG-2018) [9]:

Stopping visibility distance is the minimum distance required for a vehicle to stop at its design speed before reaching a immobile target around its path.

For roads with a slope greater than 3%, whether going up or down, the stopping visibility distance can be calculated according to the following formula:

$$D_p = 0.278Vt_p + \frac{V^2}{254\left(\left(\frac{a}{9.81}\right) \pm i\right)} \quad (1)$$

Where:

- ✓ $+i$ = Ascents with respect to the direction of circulation
- ✓ V = design speed (km/h)
- ✓ a = deceleration (m/s2)
- ✓ d = braking distance in meters
- ✓ $-i$= Descents with respect to the direction of circulation.
- ✓ i = Longitudinal slope (so by one)

For the overtaking visibility distance, it is determined as the sum of four distances, as follows:

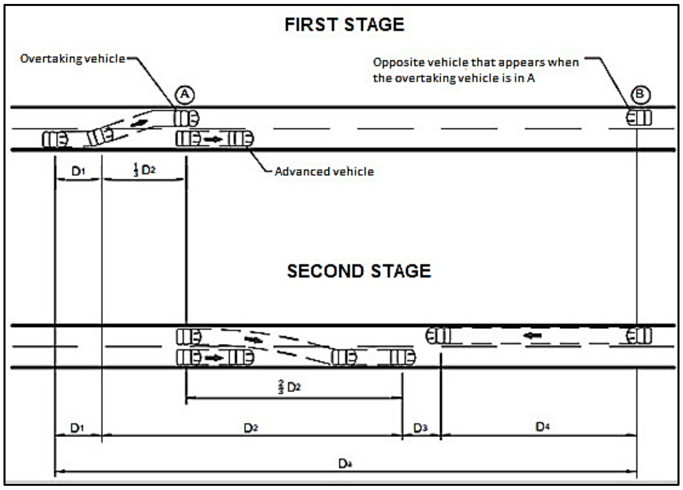

Fig. 4. Overtaking visibility distance. [9]

$$Da = D1 + D2 + D3 + D4 \quad .(2)$$

Where:

- ✓ Da = overtaking visibility distance, in meters.
- ✓ D1 = distance traveled during the time of perception and reaction, in meters.
- ✓ D2 = distance traveled by the vehicle ahead during the time from entering the opposite lane until it returns to its lane, in meters.
- ✓ D3 = safety distance, once the maneuver is completed, between the overtaking vehicle and the vehicle approaching in the opposite direction, in meters.
- ✓ D4 = distance traveled by the vehicle coming from the opposite direction (estimated at 2/3 of D2), in meters.

III. Methodology

To carry out the visibility distance evaluation using Istram, the following was carried out: First, the description of the existing geometry was carried out, where data such as current vehicle speeds, the type of vehicles that circulate in the area, the presence of vertical and horizontal signs, lane measurement, etc. After that, the topographic survey was carried out in the field using drone photogrammetry, which was divided into three work stages: Field reconnaissance, establishment of photocontrol and geodesy points, and finally the photogrammetric flight. With this, the curve lines of the area were obtained and the current representation of the road in ISTRAM was made. Already having the representation as a final result, the visibility tool is applied, in order to be able to evaluate in which sections it differs or there is a calculation error. Then, it is determined which sections or sectors comply with the stopping and overtaking visibility distance for a specific speed and fixed speed. In accordance with this, it will be possible to decide if it is possible to modify the geometry or environment through a geometric redesign or the use of preventive, informative or warning vertical signaling is proposed.

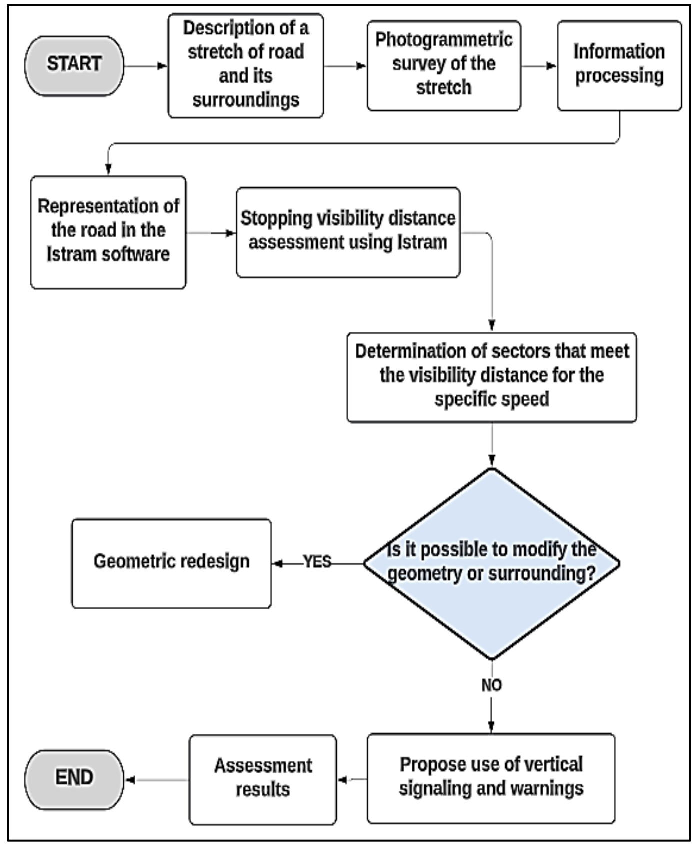

Fig. 5. Flowchart

IV. Results

The influence of roadside elements on the available visibility distance has been analyzed, highlighting the drawbacks of each of them.

For this reason, with the help of the Istram Ispol software, the calculation of the stopping and overtaking visibility distance available on roads has been developed for a fixed speed of 30km/h and a variable speed on specific sections of the road. For both situations it was possible to locate the critical points for safety in the road layout presented below:

A. *Stopping visibility Distance*

First of all, in table I, it can be seen that in the sections presented, the result of stopping visibility does not meet the necessary distance compared to the distance available for a fixed speed of 30 km/h.

TABLE I.

STOPPING VISIBILITY DISTANCE

Initial PK (m)	Final PK (m)	Fixed speed (km/h)	Necessary distance (m)	Available distance (m)
1055	1120	30	26.9	26.2
1455	1460	30	26.4	5.1
2380	2545	30	26.6	26.1
2580	2630	30	26.1	5.4
2660	2770	30	26.1	25.5
2905	2960	30	25.9	1.3

Below is Table II of non-compliance with the required distance for a speed of 30km/h according to the DG-2018 manual.

TABLE II.

NON-COMPLIANCE PERCENTAGE (DP) FOR 30KM/H

SECTION	Initial PK (m)	Final PK (m)	Fixed speed (km/h)	Non-compliance percentage
1	1055	1120	30	2.60%
2	1455	1460	30	80.68%
3	2380	2545	30	1.88%
4	2580	2630	30	79.31%
5	2660	2770	30	2.30%
6	2905	2960	30	94.98%

Secondly, Table III shows the sections where the available visibility distance is less than that necessary for a variable speed of 50 km/h.

TABLE III.

STOPPING VISIBILITY DISTANCE

Initial PK (m)	Final PK (m)	Fixed speed (km/h)	Necessary distance (m)	Available distance (m)
1020	1120	50	61.9	60.8
1245	1255	50	60.1	25.6
1430	1450	50	60.1	59.4
2345	2595	50	60.8	59.5
2625	2820	50	58.8	58.6
2905	2930	50	58.1	6.6

Table IV of non-compliance with the distance required for a speed of 50km/h according to the DG-2018 manual is presented below.

TABLE IV

NON-COMPLIANCE PERCENTAGE (DP) FOR 50KM/H

SECTION	Initial PK (m)	Final PK (m)	Fixed speed (km/h)	Non-compliance percentage
1	1020	1120	50	1.78%
2	1245	1255	50	57.40%
3	1430	1450	50	1.16%
4	2345	2595	50	2.14%
5	2625	2820	50	0.34%
6	2905	2930	50	88.64%

B. Overtaking Visibility Distance

Table V shows the evaluation of overtaking visibility distance, where there are problems of waste ground, road, embankment, or terrain (in which it would non-compliance that the available visibility is greater than necessary to overtake).

TABLE V.

OVERTAKING VISIBILITY DISTANCE

Inicial PK (m)	Final PK (m)	Fixed speed (km/h)	Necessary distance (m)	Available distance (m)	Navigation on errors
385	415	30	110	100	Problems with waste ground
435	480	30	110	100	Problems with waste ground
910	965	30	110	100	Problems with waste ground
1015	1155	30	110	106.6	Problems with road
1190	1255	30	110	100	Problems with embankment
1315	1330	30	110	80	Problems with terrain
1345	1450	30	110	106.7	Problems with road
1460	1490	30	110	100	Problems with waste ground
1925	2000	30	110	100	Problems with terrain
2420	2590	30	110	100	Problems with road
2665	2900	30	110	108.7	Problems with road

V. INTERPRETATION AND ANALYSIS

In accordance with the results achieved in chapter IV, the respective analysis of stopping and overtaking visibility distance was carried out using the tables and images obtained with the ISTRAM ISPOL software.

- In table I, where the stopping visibility distance is evaluated for the design speed of 30 km/h, there are 6 sections where the necessary distance is not met compared to the available distance. Likewise, the program indicates the sections that do not meet the minimum distance required.

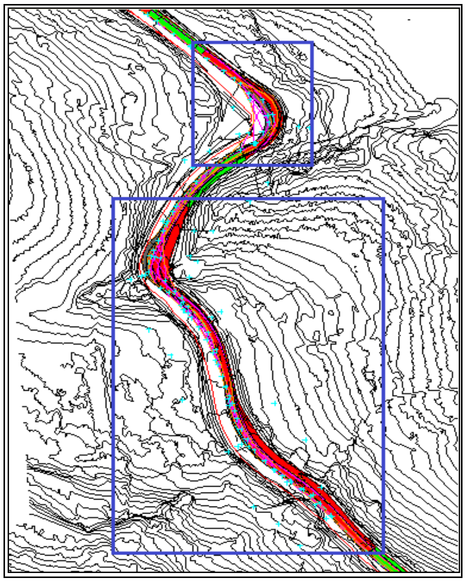

Fig. 6. Sections that do not meet the stopping visibility distance (2+380km to 2+545km and 2+580km to 2+630km)

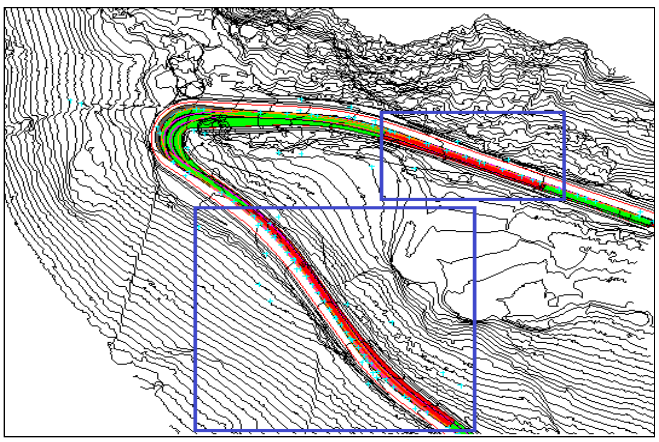

Fig. 7. Sections that do not meet the stopping visibility distance (2+660km to 2+770km and 2+905km to 2+960km)

- According to what is observed in table II in sections 2, 4 and 6 for a fixed speed of 30km/h there is a high percentage of non-compliance with 80.68%, 79.31% and 94.89% respectively in the required visibility distance of according to the road manual established in Peru. In addition, in table IV for a variable speed of 50km/h there is a higher percentage of non-compliance for the visibility distance in section 2 with 57.40% and in section 6 with 88.64%.

- In table V, where the overtaking visibility distance is evaluated for a fixed speed of 30 km/h, there are 12 sections where the minimum distance is not met compared to the available distance, due to terrain problems, waste ground, road or embankment.

- From the point of view of road safety, the following must be taken into account: Roads must be designed so that the available visibility distance is greater than that required or necessary for an emergency stop that is essential. To stop the vehicle, the necessary distance depends on certain parameters such as the speed it travels, the inclination of the ground, the coefficient of friction between the tire and the pavement, etc. Given the geometric characteristics of the road measured in the field with the design speed is 30 km/h.

- When comparing speeds between 30 km/ and 50 km/h, the stopping visibility distance of the latter would not meet the requirements of the DG-2018 manual to a greater extent, and therefore it would be necessary to propose signaling, so that road safety can be maintained, which would consist of the following points:

  - Vertical signs:
    - Maximum speed signal.
    - Signal to reduce speed in the sections that are required.
  - Containment barriers
    - These barriers will be installed along the curved section to prevent vehicles from leaving the road in the event of a road accident.

VI. CONCLUSIONS

Based on the results obtained, we can reach the following conclusions:

- For a fixed speed of 30km/h in sections 2, 4 and 6 of Table II, there is a high percentage of non-compliance with 80.68%, 79.31% and 94.89% respectively in the required visibility distance according to the specifications of the Peruvian road manual DG2018. Likewise, in table IV using a variable speed of 50km/h there is a higher percentage of non-compliance for the distance of visibility in section 2 with 57.40% and in section 6 with 88.64%. This corroborates the percentage of accidents in the project area where the incidents are mostly of the side collision or collision type with a percentage of 42.73% and distraction with 20.19%.

- The field data obtained from the highway were essential to be able to make improvements in the design of the project. By analyzing the data, critical sections that need to be redesigned or that require signaling were identified. In both cases, it was important to take into account stopping and overtaking visibility distance, and to make accurate calculations of available visibility.

It is important to mention that certain obstacles, such as mounds of sand or dense vegetation, significantly reduce the visibility available on some sections of the road. Therefore, it is necessary to take these factors into account when designing or improving a road, in order to guarantee safe and fluid circulation for all users.

- It was detected that there are horizontal curves on the highway that do not meet the specifications of the Peruvian road manual DG2018. It is recommended to add additional signaling to alert drivers of the dangers of the curve, reduce the speed limit in the curve zones so that drivers increase the perception and reaction time and add barriers to prevent vehicles from leaving the curve.

- It is recommended to specify the maximum speed allowed through the adequate signaling in the sectors where overtaking maneuvers take place. In this way we guarantee that drivers generate a safe visibility distance that can reduce the probability of accidents.

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