Road Safety Analysis at Intersections: Case of the North Entrance of Porto Nacional - TO

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Abstract— The present work aims to analyze the efficiency of the intersection located at the TO - 050 at the entrance of the city of Porto Nacional - TO, the chosen location presents negative points regarding the safety of the drivers, due to the connection of the expressway with highways. Without the addition of auxiliary lanes and poor signage, generating dangerous intersections and overtaking, and the existence of the entrance port of the municipality at the intersection that impairs the visibility of drivers. The region has large movement of cargo and passenger vehicles due to agricultural production and because it is the connecting section of the capital of the state of Tocantins (Palmas) with the municipality of Porto Nacional, consequently increasing the likelihood of accidents on the site. Therefore, the need to study conflict points and their origins is identified, guaranteeing efficient traffic flow and safety for drivers.

Keywords—Intersection; Safety; Signaling; Conflicts.

I. INTRODUCTION

According to the National Transport Confederation (CNT), the Brazilian highway modal is the main means for product flow in February 2019, the highway's participation in cargo transportation was 61.1%, in addition to the constant growth of vehicle that between January 2015 and January 2019 grew 14.8%. Consequently, a demand is created that demands greater investments in infrastructure and inspection.

Second data from Denatran (2019) Porto Nacional has a route of 30230 vehicles showing a growth of 4.7% over the year 2018. Such growth increases the search for solutions with a view to meeting road needs in a viable, economical and safe manner.

It is recommended that road improvement projects be based on future road demand, making the investment more advantageous because they have long-term positive aspects, the actual data obtained represent the current road situation that ensures the analysis of future demand.

According to DNIT (2009) the highways have meeting points, which allow access to municipalities or the arterial roads, it is essential that in the project these places have more attention, due to possible intersections, which are points of accumulation of accidents and major cause of the malfunction of the way.

DNIT (2005) states that intersections are considered areas of potential conflict, as it is requested by more than one vehicle simultaneously performing different maneuvers, consequently, are the points where the highest number of accidents occur. The absence of signaling, errors in maneuvering by drivers due to the short period to make decisions and faults in geometric characteristics aggravate possible conflicts.

Signaling contributes significantly to the proper functioning of the roads and is the main means of communication of intersection with the driver, it helps in regulating traffic and guiding drivers, minimizing accidents.

The operation of intersections significantly influences the performance of the road system, interfering with operating speed, capacity and safety. Traffic jams and functionality problems encountered on highways often occur because of inability to move traffic at intersections.

Geometrical sizing of roads considering future demand allows for better visibility, maneuverable areas with sufficient conductor reaction time, and peak flow throughput productivity minimizing congestion.

Thus, the objective of this work was to analyze the road request, proper sizing of lanes, efficient signaling, the use of auxiliary lanes, speed and proper visibility, for a good functioning of the road network under study.

II. METHODOLOGY

The traffic study and the intersections of projects made in Brazil are based on the Manual TRAFFIC - DNIT (2006) and the Intersections Project Manual - DNIT (2005), and these literatures used in this work.

The site under study (Fig. 1) has a hollow knuckle-like intersection with a gantry in the central site and main and
secondary road connections that function as the entrance and exit of one of the townships, located on TO - 050 at the entrance of the municipality of Porto Nacional - TO.

To obtain the necessary answers to the case study will be done the signs and design are necessary in order to provide greater security for society.

![Location in and study.](image)

**Fig. 1: Location in and study.**

### 2.1 TRIANGLE OF VISIBILITY FOR TRAFFIC STOPPED

The recommended distances in the visibility triangles will depend on the type of traffic control adopted at the intersection. In the case of intersections controlled by mandatory stop signs on the secondary road, turn left from the secondary road. The decision point shall be 4.40 m and 5.40 m from the edge of the main highway traffic lane.

Table 1 contains the intersection visibility distance (DVI) values controlled by the mandatory left-hand stop signaling from the secondary road:

**Table 1: Visibility distance at intersections**

| Project vehicle | Visibility distances required for a stationary vehicle to turn left on a two-lane, two-way traffic road, without center bed (m) |
|-----------------|-------------------------------------------------------------------------------------------------------------------------------|
|                 | **Main road directive speed (km / h)**                                                                                         |
|                 | **20** | **30** | **40** | **50** | **60** | **70** | **80** | **90** | **100** | **110** | **120** |
| VP              | Greide approaches up to 3%                                                                                                    |
| CO / O          | 40     | 65     | 85     | 105    | 125    | 145    | 165    | 190    | 210     | 230     | 250     |
| SR / RE         | 55     | 80     | 105    | 130    | 160    | 185    | 210    | 240    | 265     | 290     | 315     |
|                 | Greide approaches up to 4%                                                                                                    |
| VP              | 45     | 65     | 85     | 105    | 130    | 150    | 170    | 195    | 215     | 235     | 255     |
| CO / O          | 55     | 80     | 110    | 135    | 160    | 190    | 215    | 245    | 270     | 295     | 325     |
| SR / RE         | 65     | 100    | 130    | 165    | 195    | 230    | 260    | 295    | 325     | 360     | 390     |
|                 | Greide approaches up to 5%                                                                                                    |
| VP              | 45     | 65     | 90     | 110    | 130    | 155    | 175    | 200    | 220     | 240     | 265     |
2.2 MINIMUM RADIUS FOR INTERVENTION CURVES

For vehicles to be able to drive above 25km / h, it is necessary to give higher radius curves and consistent superelevation, such values as shown in Table 2.

Table 2: Minimum radii for intersecting curves.

| Design Speed (km / h) | 25 | 30 | 40 | 50 | 60 | 70 |
|----------------------|----|----|----|----|----|----|
| Transverse Friction Coefficient - f | 0.32 | 0.28 | 0.23 | 0.19 | 0.17 | 0.15 |
| Superelevation (%) | 0 | 2 | 4 | 6 | 8 | 9 |
| Minimum calculated radius (m) | 15 | 24 | 47 | 79 | 113 | 161 |
| Minimum round radius (m) | 15 | 25 | 50 | 80 | 115 | 160 |

Source: DNIT (2005).

Note:

i) The above radii are preferably adopted at the inner edge of the track.

(ii) For speeds above 70 km / h the values corresponding to the general roads shall be used.

(iii) For continuous flow the curve radii should be greater than 30m.

2.3 WIDTH OF RAMES

Table 3 shows the widths of the raceways for each type of traffic condition in combination with the type of operation, these widths will be compared to those existing at the study site. Always add the widths of the safety lanes to the widths of the rolling lanes.

Table 3: Width of conversion lanes (m)

| Runway Inner Radius (m) | Case I A lane with no foresight ahead | Case II A traffic lane predicted for passing a stationary vehicle | Case III Two traffic lanes, one or two way |
|-------------------------|--------------------------------------|------------------------------------------------|----------------------------------|
| A | B | C | A | B | C | A | B | C |
| 15 | 5.4 | 5.5 | 7.0 | 6.0 | 7.8 | 9.2 | 9.4 | 11.0 | 13.6 |
| 25 | 4.8 | 5.0 | 5.8 | 5.6 | 6.9 | 7.9 | 8.6 | 9.7 | 11.1 |
| 30 | 4.5 | 4.9 | 5.5 | 5.5 | 6.7 | 7.6 | 8.4 | 9.4 | 10.6 |
| 50 | 4.2 | 4.6 | 5.0 | 5.3 | 6.3 | 7.0 | 7.9 | 8.8 | 9.5 |
| 75 | 3.9 | 4.5 | 4.8 | 5.2 | 6.1 | 6.7 | 7.7 | 8.5 | 8.9 |
| 100 | 3.9 | 4.5 | 4.8 | 5.2 | 5.9 | 6.5 | 7.6 | 8.3 | 8.7 |
| 125 | 3.9 | 4.5 | 4.8 | 5.1 | 5.9 | 6.4 | 7.6 | 8.2 | 8.5 |
| 150 | 3.6 | 4.5 | 4.5 | 5.1 | 5.8 | 6.4 | 7.5 | 8.2 | 8.4 |
| Tangent | 3.6 | 4.2 | 4.2 | 5.0 | 5.5 | 6.1 | 7.2 | 7.9 | 7.9 |

Modification of width in face of pavement edge conditions
Shoulder
Not established
- 
Transposable curb
- 
Insurmountable curb:
  One side.
  Two sides.
  + 0.30m
  + 0.60m
  + 0.60m
  + 1.20m
Rigid Barrier:
  One side.
  Two sides.
  + 0.60m
  + 1.20m
Shoulder
stabilized on one or two
sides
Lane width for conditions
B and C may be reduced
by tangent to 3.60m if the
shoulder is equal to or
greater than 1.20m.
 Subtract the width of the
shoulder. The width shall
not be less than that
corresponding to Case 1.
 Subtract 0.60m if the
shoulder width is 1.20m or
more.

Source: DNIT (2005).

2.4 DECELERATION AND ACCELERATION RANGE SIZING

To determine the ranges of lengths will be used are Tables 4 and 5 to features m the lengths of the speed change ranges for greides up to 2% compared to the guideline speed and safe speed of the output curve / input (tracks acceleration and deceleration).

Table 4 - Length of deceleration ranges.

| Guideline Speed | Taper (m) | Deceleration range length, including taper (m) |
|-----------------|----------|-----------------------------------------------|
|                 |          | Exit curve safety speed (km / h)              |
|                 |          | 0  | 20  | 30  | 40  | 50  | 60  | 70  | 80  |
| 40              | 40       | 60 | 50  | 40  | -   | -   | -   | -   | -   |
| 50              | 45       | 75 | 70  | 60  | 45  | -   | -   | -   | -   |
| 60              | 55       | 95 | 90  | 80  | 65  | 55  | -   | -   | -   |
| 70              | 60       | 110| 105 | 95  | 85  | 70  | 60  | -   | -   |
| 80              | 70       | 130| 125 | 115 | 100 | 90  | 80  | 70  | -   |
| 90              | 80       | 145| 140 | 135 | 120 | 110 | 100 | 90  | 80  |
| 100             | 85       | 170| 165 | 155 | 145 | 135 | 120 | 100 | 85  |
| 110             | 90       | 180| 180 | 170 | 160 | 150 | 140 | 120 | 105 |
| 120             | 100      | 200| 195 | 185 | 175 | 170 | 155 | 140 | 120 |

Source: DNIT (2005).
Table 5 - Length of acceleration bands.

| Guideline Speed | Taper (m) | Acceleration range length, including taper (m) |
|-----------------|----------|-----------------------------------------------|
|                 |          | 0  | 20 | 30 | 40 | 50 | 60 | 70 | 80 |
| 40              | 40       | 60 | 50 | 40 |   |    |    |    |    |
| 50              | 45       | 90 | 70 | 60 | 45 |   |    |    |    |
| 60              | 55       | 130| 110| 100| 90 | 55 |   |    |    |
| 70              | 60       | 180| 150| 140| 120| 90 | 60 |    |    |
| 80              | 70       | 230| 210| 200| 180| 140| 100| 70 |    |
| 90              | 80       | 280| 250| 240| 220| 190| 140| 100| 80 |
| 100             | 85       | 340| 310| 290| 280| 240| 200| 170| 110|
| 110             | 90       | 390| 360| 350| 320| 290| 250| 200| 160|
| 120             | 100      | 430| 400| 390| 360| 330| 290| 240| 200|

Source: DNIT (2005).

Note: The minimum length of the deceleration and acceleration range will always be the taper indicated in the tables.

2.5 SIGNALING ANALYSIS

The analysis of the signs of the place under study will be based on the Brazilian Traffic Signal Manual, the possible flaws found in the current situation will be corrected and added to the adequacy project.

III. RESULTS AND DISCUSSIONS

From the loco checks, the sizing and possible faults related to the signaling found at the intersection were analyzed.

3.1 DIMENSION OF INTERSECTION ITEMS

The Porto Nacional City Hall made available the Portal Norte temporary signaling project, Fig. 2, which was used as a reference to verify the design of the intersection under study.

Table 6 - Design Found in Design.

| ITEMS TO INSPECT             | C | NC | COMP. (m) | NOTE                  |
|------------------------------|---|----|-----------|-----------------------|
| 01 - East Acceleration Range | x |    | 89.76     | Palmas                |
| 02 - West Acceleration Range | x |    | 89.20     | Porto National Direction |
| 03 - Eastern Deceleration Range | x |    | 89.81     | Palmas                |
| 04 - West Deceleration Range | x |    | 89.67     | Porto National Direction |
| 05 - Taper East Acceleration Range | x |    | 35.78     | Palmas                |
| 06 - Taper West Acceleration Range | x |    | 38.05     | Porto National Direction |
| 07 - Taper Eastern Deceleration Range | x |    | 36.54     | Palmas                |
| 08 - Taper West Deceleration Range | x |    | 38.80     | Porto National Direction |
| 09 - Minimum radius of East intersection curves | x |    | 61.30     | Referring to the site where the portal is located |
The distance visibility triangle in the project is approximately 25 m and the table that the DNIT (2005) recommends is 65 m for passenger vehicles, this difference in distance is discrepant to compared to reality found.

When analyzing Table 7 it is noted that in the real situation found at the intersection there is no acceleration range, and the deceleration range is shorter than the design, since the acceleration tapers are within the length recommended by DNIT (2005).

The compliment that of tapers deceleration, the rays minimum of curves, triangles visibility and the widths of the branches are close to the lengths project, but still lower than recommended by the DNIT (2005).

3.2 INTERSECTION SIGNALING

The Porto Nacional City Hall made available the temporary North Portal signaling project, which was used as a reference to verify the intersection signaling under study.

Table 8 shows the signs found in the project, where the design speed is 30 km/h and there is no kilometer nameplate.
Table 8 - Signage Found in the Project.

| ITEMS TO INSPECT            | C  | NC | AMOUNT | NOTE          |
|-----------------------------|----|----|--------|---------------|
| VERTICAL SIGNALING          | x  |    | 24     |               |
| 01 - Mandatory Stop Sign    | x  |    | 4      |               |
| 02 - Maximum permitted speed plate | x |    | 2 | 30 km / h |
| 03 - Spine Plate            | x  |    | 16     |               |
| 04 - Kilometer Nameplate    | X  |    | 0      |               |
| 05 - Sign give preference   | x  |    | 2      |               |
| HORIZONTAL SIGNALING        | x  |    | 7      |               |
| 01 - Double Line Continued / Dashed | x |    | 1      |               |
| 02 - Runway Edge Line       | x  |    | 2      | Left and right side |
| 03 - Stop Retention Line    | x  |    | 4      |               |

EVALUATION CRITERIA: C - CONSTA NC - DOES NOT

Source: Prepared by the author based on the Temporary Signaling Project (2019).

Table 9 shows the actual signage found, which does not contain mandatory stop signs, speed bumps, mileage nameplate, preference signs and stop retention lines.

Table 9 - Signaling in Loco.

| ITEMS TO INSPECT            | C  | NC | AMOUNT | NOTE          |
|-----------------------------|----|----|--------|---------------|
| VERTICAL SIGNALING          | x  |    | 2      |               |
| 01 - Mandatory Stop Sign    | x  |    | 0      |               |
| 02 - Maximum permitted speed plate | x |    | 2 | 30 km / h |
| 03 - Spine Plate            | x  |    | 0      |               |
| 04 - Kilometer Nameplate    | x  |    | 0      |               |
| 05 - Sign give preference   | x  |    | 0      |               |
| HORIZONTAL SIGNALING        | x  |    | 3      |               |
| 01 - Double Line Continued / Dashed | x |    | 1      |               |
| 02 - Runway Edge Line       | x  |    | 2      | Left and right side |
| 03 - Stop Retention Line    | x  |    | 0      |               |

EVALUATION CRITERIA: C - CONSTA NC - DOES NOT

Source: Prepared by the Author (2019).

Fig. 3 shows the actual signaling situation at two of the conflict points, noting the absence of mandatory stop signs and horizontal signaling.
One of the most alarming points of this project is the visibility of the drivers, they are impaired by the existence of the North Portal, it is within the visibility triangle and the intersection is close to a curve, with this dimensioning the driver ends up having a minor reaction, with the possibility of lateral collisions, and the intersection has virtually no signaling or speed reducers, as shown in Table 9.

With all note - the importance of supervision of intersections in our country and implementation of signage projects where it has not been executed yet. The study showed the conflicts and problems that may occur in this location, enhancing the importance of not releasing works without the execution of these projects.

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