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 s in Meto those indicated by Bring 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.

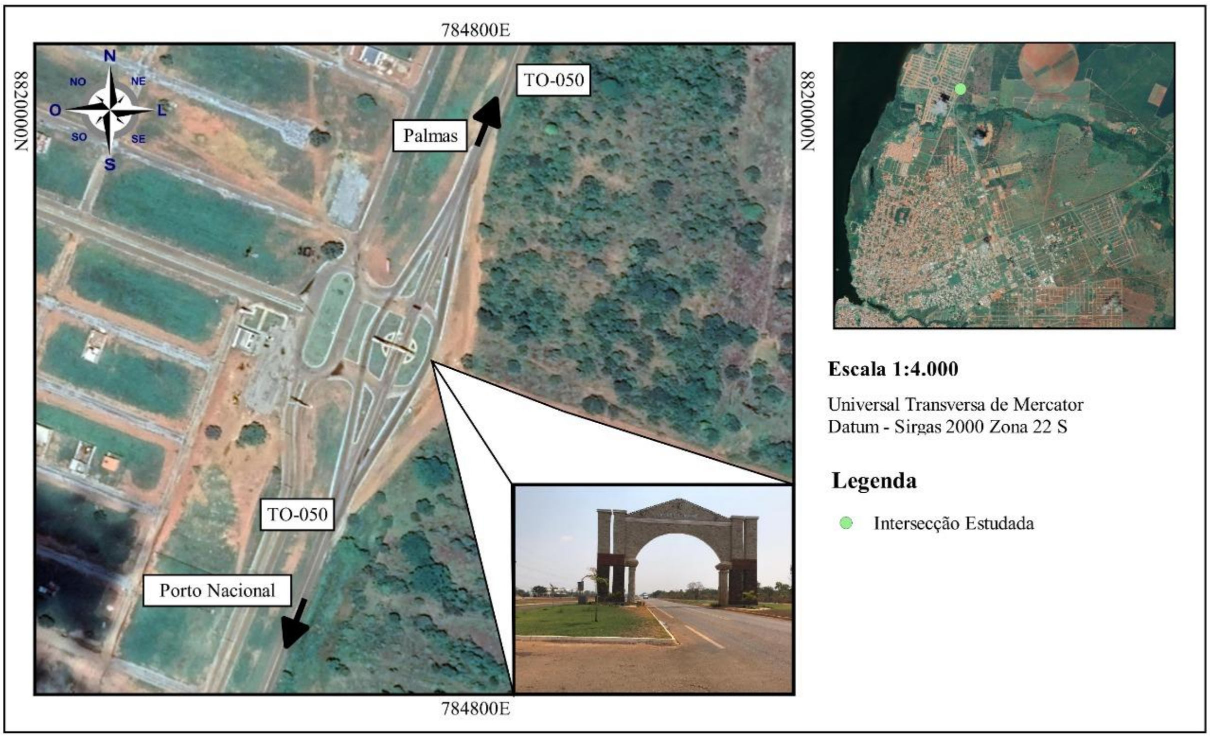

Fig. 1: Location in and study.

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
Greide approaches up to 3%											
VP	40	65	85	105	125	145	165	190	210	230	250
CO / O	55	80	105	130	160	185	210	240	265	290	315
SR / RE	65	95	130	160	190	225	255	290	320	350	385
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

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CO / O	55	85	110	140	165	195	220	250	275	305	330
SR / RE	65	100	130	165	200	230	265	300	330	365	395
Greide approaches up to 6%											
VP	45	70	90	115	135	160	180	205	225	250	270
CO / O	55	85	110	140	170	195	225	255	280	310	335
SR / RE	65	100	135	170	200	235	270	305	335	370	405

Source: DNIT (2005).

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. Rigid Barrier: One side. Two sides. Shoulder stabilized on one or two sides	- - + 0.30m + 0.60m + 0.60m + 1.20m 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.	- - - + 0.30m + 0.30m + 0.60m Subtract the width of the shoulder. The width shall not be less than that corresponding to Case 1.	- - + 0.30m + 0.60m +0.60 + 1.20m Subtract 0.60m if the shoulder width is 1.20m or more.

Source: DNIT (2005)

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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).

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Table 5 - Length of acceleration bands.

Guideline Speed	Taper (m)	Acceleration range length, including taper (m)							
		Input speed safety speed (km / h)							
		0	20	30	40	50	60	70	80
40	40	60	50	40	-	-	-	-	-
50	45	90	70	60	45	-	-	-	-
60	55	130	110	100	70	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.

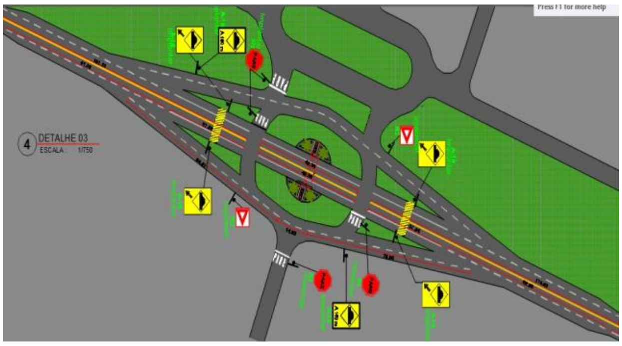

Fig. 2 - North Portal Intersection.

Based on the tables provided by DNIT (2005), it can be seen from Table 6 that the acceleration and deceleration ranges and the minimum radius of intersection curves are within the required dimensioning according to the design speed of 30 km / h, of branch widths, visibility triangles and tapers, they are smaller than those recommended by DNIT (2005), the tapers should be at least 40m.

Table 6 - Design Found in Design.

INTERSECTION ITEM DIMINATION SUPERVISORY REPORT				
ITEMS TO INSPECT	Ç	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

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10 - Minimum radius of west intersection curves	x		61,22	Referring to the site where the portal is located
11 - East Visibility Triangle	x		24,72	
12 - West Visibility Triangle	x		23,39	
13 - East Branch Width	x		7,00	
14 - West Branch Width	x		7,00	
EVALUATION CRITERIA: C - CONSTA NC - DOES NOT				

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

The distance visibility triangle in the project is approximately 25 m and the table that the DNIT (2005) recommends is 65m 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).

Table 7 - Design in Loco.

INTERSECTION ITEM DIMINATION SUPERVISORY REPORT				
ITEMS TO INSPECT	C	NC	COMP. (m)	NOTE
01 - East Acceleration Range		x	0,00	Palmas
02 - West Acceleration Range		x	0,00	Porto National Direction
03 - Eastern Deceleration Range	x		39,70	Palmas
04 - West Deceleration Range	x		75,40	Porto National Direction
05 - Taper East Acceleration Range	x		43,00	Palmas
06 - Taper West Acceleration Range	x		50,00	Porto National Direction
07 - Taper Eastern Deceleration Range	x		30,80	Palmas
08 - Taper West Deceleration Range	x		38,30	Porto National Direction
09 - Minimum radius of East intersection curves	x		59,60	Referring to the site where the portal is located
10 - Minimum radius of west intersection curves	x		63,65	Referring to the site where the portal is located
11 - East Visibility Triangle	x		24,30	
12 - West Visibility Triangle	x		23,40	
13 - East Branch Width	x		6,84	
14 - West Branch Width	x		6,76	
EVALUATION CRITERIA: C - CONS TA NC - DOES NOT				

Source: Prepared by the Author (2019).

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 30km / h and there is no kilometer nameplate.

Table 8 - Signage Found in the Project.

SIGNALING SURVEILLANCE REPORT				
ITEMS TO INSPECT	C	NC	AMOUNT	NOTE
VERTICAL SIGNALING	x		24	
01 - Mandatory Stop Sign	x		4	
02 - Maximum permitted speed plate	x		2	30km / 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.

SIGNALING SURVEILLANCE REPORT				
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.

Fig. 3: Conflict Points.

Fig. 4 shows a point of conflict where we established the east visibility triangle, when checking it noted that the North Portal interferes with driver visibility, this interference can aggravate accidents at that location, as it is an intersection for entry into an allotment.

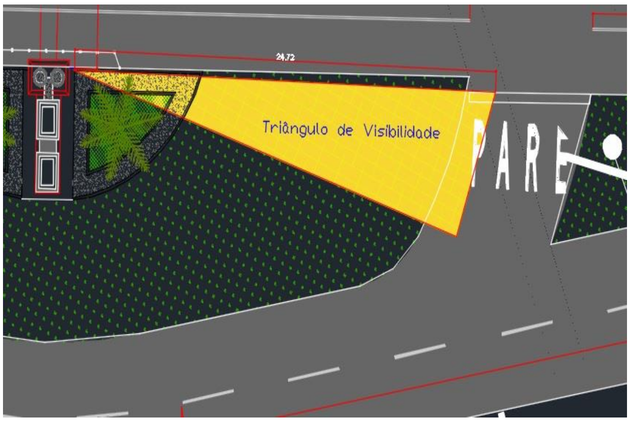

Fig. 4: East Visibility Triangle of the Temporary Signaling Project.

Numbered sequentially using 1, 2, 3, etc. Subheadings are numbered 1.1, 1.2, etc. If a subsection must be further divided, the numbers 1.1.1, 1.1.2, etc.

IV. CONCLUSION

The verifications made in this work pointed out the importance of the signaling and main and auxiliary lanes with proper dimensioning, when comparing the design and the intersection situation in loco we noticed several problems.

Initially we analyzed the acceleration and deceleration ranges, we found that the deceleration ranges were smaller than the design, in addition to the inexistence of the acceleration range that forces the driver to make sudden entries in the main lane, which can lead to several conflicts such as rear-end collisions. account of braking and design speed established.

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.

REFERENCES

[1] BRAZIL. Law no. 9503 of 23 September 1997. CODIG Brazilian Traffic the, Annex I. Available at: < http://www.planalto.gov.br/ccivil_03/leis/l9503.htm >. Accessed May 6, 2019.

[2] CONTRAN, National Traffic Council. Brasilia. **Brazilian Manual of Traffic Signals.** 2nd ed., 2007. Vol. I, II, III, IV, V, VI and VII. [Manual].

[3] DENATRAN, National Traffic Department. **Statistical Report: Brazil 2019** . Available at: < http://www.denatran.gov.br/estatistica/237-frota-veiculos >. Accessed May 6, 2019.

[4] DNIT - National Department of Transport Infrastructure. Rio de Janeiro - Publication IPR - 723. **Traffic Studies Manual** , 2006. 388p. [Manual].

[5] DNIT - National Department of Transport Infrastructure. Rio de Janeiro - Publication IPR - 718. **Intersection Design Manual.** 2.ed., 2005. 530p. [Manual].

[6] FAVERO, Renan. Traffic analysis and road solutions: case study at an intersection in the city of Santa Maria - RS. 2017. 128f. **Monograph** (Bachelor of Civil Engineering). Federal University of Santa Maria, Santa Maria, 2017.

[7] GOOGLE EARTH. **Study Area Intersection** , 2019. Available at: < https://earth.google.com/web/@-10.66496978,-48.39711189,227.18591345a,668.88224721d,35y,20.87600528h,5.85025247t,0r/data=ChMaEQoJL20vMGt3 >. Accessed on: April 15, 2019.

[8] GUERREIRO, GCM Signaling level road interventions. 2012. 289f. **Dissertation** (Master in Civil Engineering). Department of Civil Engineering, Faculty of Engineering University of Porto, Porto, Portugal, 2012.

[9] LEAL JÚNIOR, Francisco de Sousa. 2017. 68f. Study on the domain of federal highways occupied by socially vulnerable families. **Monograph** (Specialist in Road Operations). Technological Center, Federal University of Santa Catarina, Brasilia, 2017.

https://dx.doi.org/10.22161/ijaers.611.30 *ISSN: 2349-6495(P) | 2456-1908(O)*

[10] LEAL, BAB Analysis of the relationship of the characteristics of highways and urban roads with the causes of accidents. 2014. 120f. **Monograph** (Bachelor of Civil Engineering) - Polytechnic School, Federal University of Rio de Janeiro, Rio de Janeiro, 2014.

[11] PEREIRA NETO, WA; WIDMER, JA Compatibility of gearchanges for heavy vehicle traffic on Brazilian highways. **Transport,** v. XVI, no. 2, p. 32-40, ten. 2018.

[12] SANTOS, Cristiano Zulianello. BR-101 traffic study in the southern stretch of the state of Rio de Janeiro using the highway capacity manual method 2010. 2013. 84f. **Monograph** (Bachelor of Civil Engineering). Department of Civil Engineering, Federal University of Santa Catarina, Florianópolis, 2013.

[13] VALIM, Lucas Maiolini; ALVES, Yony Brugnolo. The development of Brazilian road intersections. Department of Buildings and Roads of Minas Gerais, Minas Gerais, 2016.