ADJUSTING PROCEDURE FOR DETERMINING THE TRAVEL SPEED THROUGH THE HCM 2010 METHODOLOGY FOR BRAZILIAN URBAN ROADS

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ABSTRACT

The methodologies presented by the Highway Capacity Manual (HCM) is the most used for the study of urban roads in the technical community Brazilian. These methodologies are based on the identification and measurement of the average travel speed (VMR) developed by the stream of traffic on a road segment. This study aims to find an adjustment in the method for determining the VMR of vehicles on urban roads, which is used in the HCM 2010 methodology for analysis of capacity and level of service in sections of roads in the city of Brasilia - DF. This study was developed from analysis of primary data collected on arterial roads by an adaptation of the methodology do HCM that can be used with confidence on urban roads in Brazil.

KEYWORDS: HCM 2010, urban roads, level service.

1 INTRODUCTION

The first documents to study the concepts of service level and capacity in various forms of transportation, the study was conducted in the United States by the Transportation Research Board, meeting in the Highway Capacity Manual (HCM), which incorporate theoretical knowledge since 1950 practices and experiences in their procedures, becoming an important source of reference for transport specialists in evaluating performance of road systems (TRB 2010).

The methodologies presented by the HCM are the most used urban roads we study the technical community Brazilian, for purposes of planning, design and operation (Paula 2006). Therefore, it is necessary to investigate whether this methodology is valid for national reality, for adopting an erroneous assessment would generate a negative impact on the transportation system.

The editions of 2000 and 2010 HCM methodologies introduced for calculating the capacity and level of service in urban areas, based mainly on the average travel speed (VMR) also known as the speed developed by the current m traffic on a stretch of track. This paper makes an analysis of the methodology, considering its shortcomings with respect to what occurs on urban roads Brazilian.

Under this scenario, the present study aimed to develop a method of determining average travel speed (VMR) of vehicles on urban roads, the HCM methodology used in 2010 to sections Brazilian way. From analysis of primary data collected in the field, pretending to do an adaptation of the HCM methodologies that can be used reliably in studies of urban roads of Brazil, proposing conceptual changes and adaptations of the method, if necessary, from two results obtained give adequacy verification using statistical analyzes.

2 STUDIES RELATED TO THE ADAPTATION HCM

HCM methodologies, in most cases, cannot be applied directly given the variability of the behavior of pedestrians and drivers in the use of road infrastructure, climate, topography and vehicle study regions, which are different conditions presented in North America. Studies by Prassas (1999) & Loureiro et al. (2004) helped identify the HCM and the use of their methods has several shortcomings and limitations in their methodologies when applied in different places.

In Brazil Gasparini (2002) analyze the suitability of the HCM 2000 for the study of urban roads Brazilian, investigating the sufficiency of the parameters already used by the methodology of the HCM 2000 related to the determination of the speed of travel, and other parameters that can influence the speed. The main conclusion of that study was that the distribution and variation of flows in the traffic lanes, and traffic composition vary considerably and should influence the average speed of travel (VMR), showing that the travel times collected in field were consistently higher than those calculated by the method of the HCM 2000, indicating their unsuitability for the reality on the tracks analyzed.

Paula (2006) proposed an adaptation of the HCM 2000 for analysis and classification of the level of service of urban roads in Fortaleza. His research found estimated average travel speed (for the HCM) significantly different from those obtained in field research results, which did not present a specific pattern having overestimated and underestimated values relative to the values obtained by the HCM. With this, the studies found that the estimation method VMR is not calibrated, by ignoring aspects directly related to the operational characteristics of the arterial roads of Fortaleza and thus its use is not suitable for precise analysis validations operating in this city.

The methodology for determining level of service on urban roads by motor multimodal analysis submitted by the HCM 2010 is defined as a set of four stages (Figure 1). The first for determining the speed of free-base (VFLB) flow; the second for determining the average travel speed (VMR) of the stretches of path analysis; the third to determine the average rate and fourth stops for determining the level of service of the stretch of road, based on the traveling speed expressed as a percentage of the speed of free-flow basis. Importantly, each of these variables contain parameters that must be calibrated and validated for use in Brazilian cities.

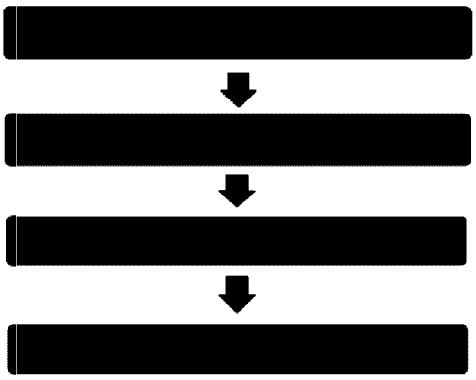

FIGURE 1 HCM 2010 Methodology for estimating the los of urban roads

The estimate of the average travel speed (VMR) of an urban corridor considers two variables: the average time on the move and the total average delay dispensed in the distance, observing all the traffic stream, Equation 1. These variables contain parameters that must be calibrated and validated for use in Brazilian cities that are consistent with the physical and operational characteristics of the existing road system in Brazil, due to the fact that this methodology has been developed to the reality of a country with great economic, social, cultural, and road systems have quite different geometrical and operational characteristics, such as differences in the United States.

$$VMR = \frac{3600L}{5280\left(t_r + d_t\right)} \quad (1)$$

where L = segment extension;
t_r = the average time on the move; and
d_t = the total average delay.

3 ANALYSIS METHOD OF HCM 2010 FOR URBAN ROADS

3.1 Elements of Analysis stretch urban roads

The manual HCM 2010 methodologies consider in a number of model-based analysis of traffic flow on urban roads calculations. The calculations are used to estimate the performance of urban roads on the basis of speed of travel times and stop rates for a track segment analyzed. Urban roads are composed of several segments, through their individual analysis, giving the performance of a whole stretch of road (Figure 2).

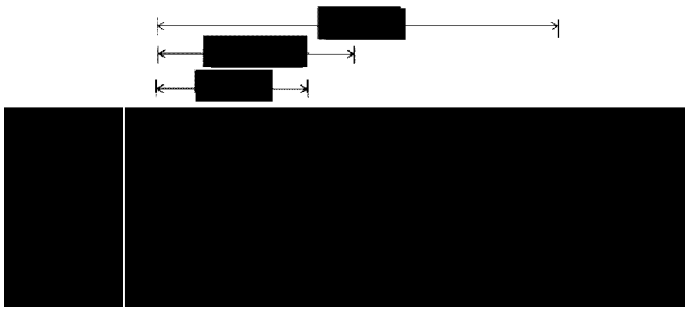

FIGURE 2 Elements of analysis stretch urban roads

The methodology of the HCM is used for the analysis of a or more segments that make up a stretch of an urban road, provided they have a length between 1.6 to 3.2 kilometers in central urban areas, and 2.4 to 8 km in other areas, and may be single or double meaning, and must be analyzed separately each direction. Way segments analyzed are characterized by a type of traffic control (traffic lights or stop signs silk step), which define the beginning and end of the segment. The spacing of these traffic control points and segment lengths vary between 122-965 meters urban roads.

In addition, measures to estimate the performance of each segment within the meaning given parameters include trip travel speed, stop rates and perception of travel by the driver which is an indication of relative satisfaction of the traveler in relation to the service provided to throughout the segment. The calculation and determination of these parameters is used to determine the level of service of urban roads. The variables that are considered for calculating service level are displayed in Figure 3.

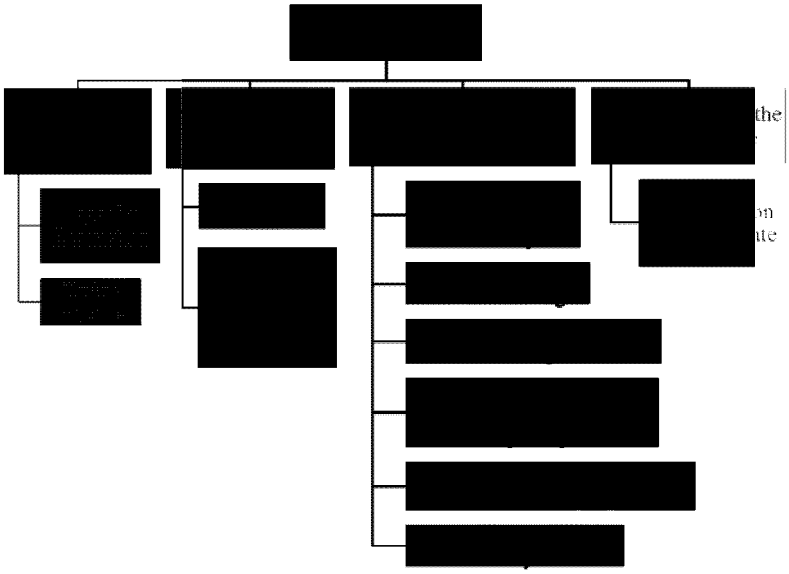

FIGURE 3 Methodology for urban roads segments

3.2 Limitations of the methodology

In general, the methodology used in the HCM 2010 manual can be used to validate the performance of most traffic flows traveling along a segment of a route. However, the methodology does not address all traffic conditions or types of control. If you have one or more of these constraints, which can have a major influenza in performing a route, consider using other methodologies or tools in analyzing performance of a road.

The methodology does not take into account the effect of the following conditions in the operational performance of a segment of a road.

- Parking along the segment
- Variability in the type of segment length
- Capacity constraints between intersections (straits points)
- Queuing of vehicles at the entrance to the intersection
- Stops in the segment due to turning vehicles to access the point
- Bicycles share the road vehicular traffic
- Congestion at intersections or crossings of railways that disrupt traffic.

4 METHODOLOGY

This research tried to study the behavior of traffic flow on urban arterial roads considering that such pathways are responsible for much of the movement of passenger traffic in cities. In this way, we intended to choose a sample of roads in the city of Brasilia so that you can verify the adequacy of the methodology of the HCM 2010 for arterial roads in the city and propose the necessary adaptations for use in local reality.

The proposed methodology was structured in four stages.

4.1 Selected locations for the Study

The proposed verification of the adequacy of the 2010 HCM methodology study was conducted on roads in the city of Brasilia with characteristics of arterial roads with interrupted flow. The road system of the Federal District of Brasilia is comprised of a set of tracks that make up the urban area of the Plano Piloto.

The urban road system of the Plano Piloto, is composed mostly of tracks that concentrate the largest flows of travel, and are classified from a functional point of view, as secondary arterials, collectors, and local roads park, having the role of connect places large demands and urban centers.

By the need to know the reality of Brazilian pathways were selected arterial roads W-3 and L-2 do Plano Piloto of Brasilia, had characteristics as land use, composition of traffic and geometry of roads, among other similar type of classification of track manually HCM includes factors. Similarly, because it is a planned city road, where you can change the operational behavior of traffic, such paths chosen have similar operating characteristics to any type of Brazilian pathways (Figure 4).

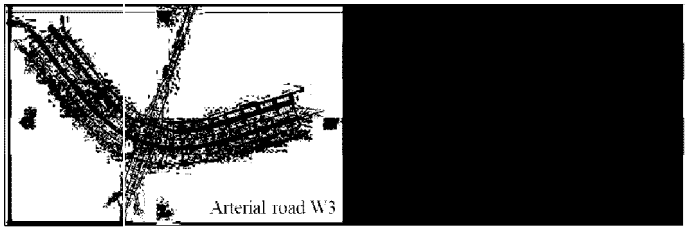

FIGURE 4 Corridors of the chosen sample

4.2 Studies of traffic volumes, speed and delay

In all segments of the paths taken were made speed and delay investigations and studies on traffic volumes (traffic composition, distribution sense and rail traffic). Thus, data collections determinations contemplated movement of vehicles on the stretches and environmental characterization (measurements of roads, location of points of access into and out of the way, location of bus stops, location of access points parking, pedestrian crossings, etc.).

The collection of information for the parameters of traffic volumes were made by means of field using camera equipment, located at the intersections that make the stretch, during periods of peak to peak in the morning and afternoon (1 hour) day of the week from Tuesday to Thursday (Figure 5).

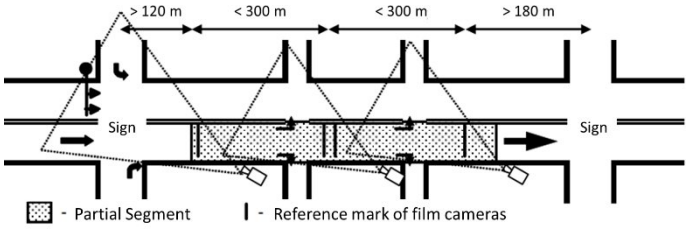

FIGURE 5 Location of film cameras

The speed and delay study were published in all the corridors of the selected samples, recording values of stroke and tempo delay, by the method of using GPS-test vehicle, walking traffic stream as suggested Manual Traffic Brazilian (DNIT 2006). Through speed information recorded by the GPS second, the estimated travel times and delays blocks, allowing you to see the location of the points of delay along the stretches.

For every vehicle or group of vehicles, the average travel speed is calculated by dividing the sum of its traversed by the sum of the total travel time lengths. If all groups of vehicles travel the same length, the average speed is obtained by dividing the path length traveled by the time average of the runs. Therefore, the average speed of travel is a spatial average speed based on the length.

4.3 Operational Characterization of the corridors of sample

With the collected data to verify the adequacy try the second method HCM, by comparing the results obtained in field with HCM estimates of average travel speed.

They were made for each pathway analysis by developing templates for characterization, using the following parameters.

- The length of the stretches and of the segments
- Time moving between signalized intersections
- Control the delay at intersections
- Average travel speed
- Level of service.

The determination of the rates was made with the use of GPS, which capture information about the test vehicle during the travel time on the route of each of the tracts analyzed. The type of variables that captures this type of equipment allowed make determinations average travel speed and the average speed of travel, plus time delay and its location along the stretch by velocity profiles and georeferenced software (Figure 6).

FIGURE 6 Speed profiles

4.4 Operational Characterization of the corridors of sample

The determination of the level of service using the estimation method and the manual method of field observations, summarized in Table 1 represent traffic assessments in the four analyzed arterial stretches. It can be seen that the determination of service levels in the four

tracts have different evaluations for each method, keeping very close results, which can generate overestimated or underestimated relative to what happens in reality solutions.

The differences in the parameters used for the determination of the VMR are justified by the adequacy that needs to be made in the manual to be employed in the Brazilian roads. These differences obey the estimation method used by the manual and is based on the free flow velocity for the estimation of the travel times including the delays and later calculation of the average speed of the course.

The differences between the Manuel method and the software obey that the program does not allow many decimal boxes showing these small variations of results. For this ration, closer results will be obtained between the method of estimation of the manual and the method collected in the field.

TABLE 1 Summary Of The Variables In Each Segment That Make The Intervals Analyzed

Stretch 1 W-3 North	1	269	19,25	18,02	17,64	50,31	53,77	54,90	B	B	B
	2	318	21,89	20,04	24,21	52,30	57,12	47,29	B	B	B
	3	94	13,61	11,76	10,3	24,86	28,74	32,85	E	D	D
	4	217	17,51	15,70	17,3	44,61	49,74	45,16	C	B	C
	5	246	18,81	16,77	20,27	47,08	52,80	43,69	B	B	C
Stretch 2 W-3 South	1	151	15,31	13,08	13,66	35,51	41,52	39,80	C	C	C
	2	123	13,94	12,54	13,49	31,76	35,34	32,82	D	C	D
	3	109	14,13	12,10	11,39	27,77	32,46	34,45	D	D	D
	4	336	22,38	20,74	29,9	54,05	58,31	40,45	B	A	C
Stretch 3 L-2 North											
Stretch 4 L-2 South											

The VMR calculated by the three methods grows when the segment extension values are less than 100 m and greater than 200 m. In this way, these two values become an ideal range to obtain more accurate estimates of velocity in this type of track. According to Prassas (1999), the average speed of traffic increases in segments 108 longer where the effect of the extension of the segment in the speed is independent of the volume.

5 ADVANTAGE OF THE VMR BY MEANS OF ESTIMATING THE EFFECTIVE SHIFTING TIME

The values of travel time and VMP observed in the field gave results above and below, respectively, to the values obtained by the HCM estimation methods. To evaluate the margin of error of the estimation obtained by the HCM in relation to the data obtained in the field, equation 2 was used (DNIT, 2006).

$$\Delta\% = \left[\frac{Estimated}{Observado} - 1 \right] * 100 \qquad (2)$$

The results obtained for the four stretches of tracks are shown in Table 2.

TABLE 2 VMR Results Of The Sections Of Roads Analyzed

Stretch 1 W-3 North	1	269	19,25	17,64	50,31	54,90	9,13	**-8,36**
	2	318	21,89	24,21	52,30	47,29	-9,58	**10,60**
	3	94	13,61	10,3	24,86	32,85	32,14	**-24,32**
	4	217	17,51	17,3	44,61	45,16	1,21	**-1,20**
	5	246	18,81	20,27	47,08	43,69	-7,20	**7,76**
Stretch 2 W-3 South	1	151	15,31	13,66	35,51	39,80	12,08	**-10,78**
	2	123	13,94	13,49	31,76	32,82	3,34	**-3,23**
	3	109	14,13	11,39	27,77	34,45	24,06	**-19,39**
	4	336	22,38	29,9	54,05	40,45	-25,15	**33,60**
Stretch 3 L-2 North								
Stretch 4 L-2 South								

The difference between the data of time and average speeds of travel has an average value of 0.10%, corresponding to 1.83 seconds and 5.13 km / h of difference in the total of 15 segments that make up the four stretches. Of these values, 50% are above and below the values estimated by the manual, however, it is difficult to estimate the VMP formula of the manual for the error found, because it is not possible to certify how far they are from the actual value.

From the previous one, it can be affirmed that the model used by the HCM manual correctly estimates the behavior of the actual speed of travel, however, with scalar error demanding by calibration for the adequate determination of the level of service in the Brazilian roads.

5.1 Regression model used to estimate effective travel times

The analysis initially focuses on a regression model that includes the effect of all variables collected in the field such as: traffic data (input volume, volume remaining in the segment), segment extension, number of accesses, Speed of free flow, percentage of vehicle conversions, track geometry, effective travel times (T_R) and delays (estimated by manual) to estimate the average speed of travel.

In the proposed VMR estimation model in the Brasilia Pilot Plan, the effective displacement time was chosen as the dependent variable for the calibration of the model, which, together with the delays estimated by the manual, determines the travel time. With this value the average speed of the course is calculated. The analysis focused initially on the fact of including the effect of the free-flow velocity, and the extension of the segment, to estimate the effective displacement time.

The statistics related to the proposed model are presented in Table 3, which shows the transformed variables and the regression model to estimate the effective displacement time. The values of the calibrated coefficients and the equation presented at the end of the table can be used to estimate the average speed of travel and determine the levels of service in urban roads of Brasília of the arterial

type from the determination of the effective displacement times and the estimated delays Manual. The R^2 for the model is 0.94, which indicates that 94% of the variability of the data is explained by the model and the missing 6% are considered as the margin of error of the model. The model's estimated standard error is 2.7 seconds.

It is important to clarify that the proposed model does not take into account the delays generated in the trips of direct form, being used only its indirect form through the values estimated by the manual for the determination of the route time. Analyzes of the delay parameters generate larger numbers of variables that make it difficult to correlate the model, besides the need for specific studies on delays not done in this research. The proposed model attempts to adapt the manual to the level of analysis of velocities and travel times by segment, which generates results very close to the Brazilian reality. Table 4 shows the results obtained by the method estimated by the manual, the observation method in Field and the proposed model.

TABLE 3 Statistical Model Of Effective Displacement Time

R^2:	0,939388842
Observation n_o:	**764 (1031 Vehicles)**
Default error e_p:	= 2,70 seconds

Variable	Variable Name	Unit	Minimum	Maximum
T_R	Effective travel time	Seg.	6	53
E_S	Segment length	km	0,094	0,663
VFLB	Free-base flow rate	km/h	55,5	67,1

Variable	Coefficients	Default error	Stat t	Values-P
Intersection	14,1725862	2,0961973	6,76109351	2,727E-11
Variable E_S	69,3427257	1,3079079	53,0180475	1,00E-257
Variable *VFLB*	-0,2153163	0,0406298	-5,29945572	1,522E-07

$$T_R = 14{,}173 + 69{,}343 * (E_S) - 0{,}215 * (VFLB)$$

TABLE 4 Relationship Of Results Of Estimated, Observed And Proposed Model

Stretch 1 W-3 North	1	269	61,5	19,25	17,64	20,24	50,31	54,90	47,85	B	B	B
	2	318	62,9	21,89	24,21	23,91	52,30	47,29	47,88	B	B	B
	3	94	51,5	13,61	10,3	10,92	24,86	32,85	30,99	E	D	D
	4	217	59,4	17,51	17,3	17,75	44,61	45,16	44,01	C	C	C
	5	246	60,8	18,81	20,27	19,43	47,08	43,69	45,58	B	C	C
Stretch 2 W-3 South	1	151	55,2	15,31	13,66	14,44	35,51	39,80	37,65	C	C	C
	2	123	51,7	13,94	13,49	12,08	31,76	32,82	36,66	D	D	C
	3	109	51,5	14,13	11,39	12,05	27,77	34,45	32,56	D	D	D
	4	336	63,5	22,38	29,9	24,72	54,05	40,45	48,93	B	C	B
Stretch 3 L-2 North												
Stretch 4 L-2 South												

6 CONCLUSIONS

The HCM methodology for urban road analysis has a base structure that has improved with each of the manual updates. All these updates allow the manual to be adjusted to represent the road characteristics, closer to the reality that happens in the roads, to improve the accuracy of the model for the determination of the service levels and the estimation of the average speed of the route.

Through this study it can be analyzed that many considerations adopted by the HCM are incompatible for an adequate operational evaluation of Brazilian urban roads.

The use of pedestrian crossing points to divide the segments allows obtaining N.S indexes closer to those observed in the field.

When comparing the results of VMR observed in the field and the speeds estimated by the manual, one can see values by very close range, being some bigger and others smaller of the real values. This is due to the fact that the average path velocity estimation model employed by the manual is based on the free flow velocity, resulting in larger estimates of effective travel time and shorter delay times.

It is concluded that many considerations adopted by the HCM are incompatible with an adequate operational evaluation of the Brazilian urban roads, considering that the geometry and the operational mode of transit in Brasilia are different from the United States (country for which the manual was created). As it is in common use in this city the use of speed surveillance (radars) that limits the speed of the drivers, it is not possible to generate very high speeds as specified in the manual, at the rate of 40 km / h and 90 km / h.

The variable that most affects the determination of VMP is the extension of the segment, since it has been proven that variations smaller than 100 m and greater than 200 m make the differences of velocities by the two methods, estimated and observed, greater, recommending making choices of Segments in this length range.

Analyzing the results in the field, it was found that the extension of the segment and the free flow velocity are the factors that most influence in the proposed model. The free-flow velocity is one of the important input variables in the HCM methodology for urban roads.

The actual displacement times estimated by the HCM manual are lower compared to those observed in the field and those estimated by the proposed model, especially for extensions of longer segments. It was found in the effective time-by-segment time graphs that by increasing the length of the segment the values of T_R are greater than those given by the manual.

The travel time is sensitive to the free-flow velocity rate presented in the segment, and the proposed model calibrates the effective displacement time estimation model of the HCM manual.

The procedures of the proposed model are intended to improve the accuracy in the estimation of operational service levels of the Brasilia roads as a function of the calibration of travel times obtained for these routes.

The methodology for determining the service level of an urban route in the HCM 2010 manual should be understood as a methodology that estimates the traffic effects of the roads and, based on these simulations, calculates road performance indicators. For this reason, this methodology should not be used as a rule for the evaluation of routes, but should be used as a calculation guide that must be adjusted and modified for each type of conditions.

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