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DETERMINATION OF CAPACITY AT TRAFFIC WARDEN CONTROLLED INTERSECTION USING FIXED-TIME SIGNALISED INTERSECTION CAPACITY MODEL

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ABSTRACT: *Models have been developed in literature for the determination of capacity at fixed-time signalised intersection. In Nigeria and some developing economy the human controlled intersection is prevalent where the recurring green time and cycle length are not fixed but vary. A 15-minute study was carried out for 7 days at AM, afternoon and PM peak periods during which the signalization pattern and time allocation of right-of-way as carried out by the human traffic controllers at the study location was observed. The ratio of the total green time (gt) allotted to an approach during the 15-minute study period to the study period (900 seconds) which is taken as the cycle length (Cl), gave the green time/cycle length ratio needed as input to compute capacity in fixed-time signalized intersection capacity model. The approach used in the study is recommended for computing capacity at a traffic warden controlled intersection as it overcomes the difficulty encountered in using the manual method of delay survey where the stopped and non-stopping vehicles on an approach is counted particularly when the queue length on an approach is long.*
KEYWORDS: *Capacity, intersection, signalization, green time, cycle length*

INTRODUCTION

There is always the need to carry out periodic evaluation of traffic performance of fixed facilities both the links and nodes. It is presently noticed that there is a rising tide of traffic congestion in the Ilorin metropolis, Nigeria, which is seriously threatening the economic and social life of the city and could become an endemic problem if not quickly arrested. In an urban road network, the most critical points from capacity, congestion and safety viewpoints are the nodes (Ogden, 1991). They frequently constitute the bottleneck of the traffic system in Ilorin as elsewhere and need special attention as already advocated for Ilorin (Ogunsanya, 1984) and Lagos (Adenle, 1981) townships. A parameter that is needed to determine the level of service at a signalized intersection is the capacity of the facility (HCM, 2000).

Existing model has been developed in literature (HCM, 2000) and used for determination of capacity at fixed-time signalized intersection. In Nigeria, however, the controlled intersections are manned major by human traffic controllers rather than fixed-time electronic signals. The study adopts the capacity model developed for fixed-time signalized intersection to compute the capacity of a traffic warden controlled intersection where the green time and cycle length are not fixed. The objective of the study therefore is to determine the capacity at a traffic warden controlled intersection using the capacity model for fixed-time signalized intersection.

MATERIALS AND METHODS - Study Area

☐ Geometric layout and traffic management

The study location is Challenge intersection in Ilorin metropolis, Nigeria. The intersection is a T-type time sharing intersection controlled by human traffic controllers between 7:00am and 8:00pm. When not controlled it operates as a priority intersections. The three approaches include, the minor (Ahmadu Bello approach) intersecting the two major approaches (namely the UBA approach and the Post Office approach) at approximately right angle. All the legs are separated by a median. Whereas the UBA approach and Post Office approach have three lanes each, Ahmadu Bello approach has only two lanes. All the approaches are paved with asphalt and the surfacing are in good condition. The pavements however have no lane markings.

☐ Vehicle Movement

Intersection capacity analysis can be performed at different levels of detail. These include; (i) analysis by total approach flow (ii) analysis by lane groups, and (iii) lane-by-lane analysis, where recognition is given to unequal lane utilization (Akcelik, 1998). As a result of the non existence of lane markings and stop lines, there is a prevalent loose lane discipline at the study location. The driving

habit at approach of the intersection is for vehicles to want to join the approach lane with the shortest queue length irrespective of the intended movement at the intersection. All the three probable movements of whether through, left turning or right turning vehicles manifest close to or at the intersection stop line thereby causing obstruction to free flow of traffic with turbulent consequences on the delay functions as well as the collection of desired data. In other words, no exclusive left or right turn lanes are provided and traffic sort out itself just at the moment turns are to be made (Okunlola, 2002). It is therefore difficult to categorize or treat vehicles based on their turning movement patterns or lane groups at the intersection. Thus in the study the vehicles movements at the intersection and capacity determination are based on an approach level of analysis rather than lane group or lane-by-lane analysis.

Green time/Cycle length determination

A 15-minute study was carried out for 7 days at AM, afternoon and PM peak periods during which the signalization pattern and time allocation of right-of-way as carried out by the human traffic controllers at the study location was observed. A record is taken of the time period of the right-of-way (green time) granted to each approach leg in each cycle of operation. The time record was kept for all the cycles observed during the simultaneous 15-minute observation period. The various green times for each approach during the 15-minute period were summed up to obtain the total green time allotted to each approach during the 15-minute study period. The ratio of the total green time (gt) allotted to an approach related to the 15 minutes (900 seconds) observation period which is taken as the cycle length (Cl), gave the green time/cycle length ratio needed as input to compute the intersection capacity in fixed-time signalized intersection capacity model (Akgungor and Bullen, 2007; HCM, 2000) shown in equation 1.

Capacity Model

Intersection approach capacity is the maximum rate of flow, which may pass through the intersection by that approach or lane group under the prevailing roadway, traffic and signalization conditions. The capacity of fixed-time signalized intersection is based on the concept of saturation flow rate and is obtained from equation 1 (Akgungor and Bullen, 2007; HCM, 2000).

$$C_i = s_i \times (gt_i/Cl) \quad (1)$$

where: C_i *= capacity of lane group or approach i (vehicles/hr)*
s_i *= saturation flow rate for lane group or approach i (vehicle /hr of green)*
gt_i *= green time for lane group or approach i*
Cl *= cycle length*

The equation for estimating saturation flow rate (s_i*) is given as equation 2*

$$s_i = S_o N f_w f_{HV} f_g f_p f_{bb} f_a f_{RT} f_{LT} \quad (2)$$

where: s_i *= saturation flow rate for the lane group or approach, expressed as a total for all lanes in the lane group or approach under prevailing roadway and traffic conditions (vehicle/hr green).*

S_o = *ideal saturation flow rate per lane, usually 1800 passenger cars per hour of green time per lane*
N = *number of lanes is the lane group*
f_w = *adjustment factor for lane width; 12-ft or 3.65m lane are standard*
f_{HV} = *adjustment factor for heavy vehicle in the traffic stream*
f_g = *adjustment factor for approach grade*
f_p = *adjustment factor for existence of a parking lane adjacent to the lane group and parking activity in that lane*
f_{bb} = *adjustment factor for blocking effect of local buses stopping within the intersection area*
f_a = *adjustment factor for area type*
f_{RT} = *adjustment factor for right turns in the lane group*
f_{LT} = *adjustment factor for left turns in the lane group*

RESULTS

☐ ***Traffic signalization pattern***

There are noticed similarities in the operations of traffic wardens and traffic signals. There is a noticed sequence that is maintained by the traffic controllers in allotting the right of way to the intersecting approaches as is the pattern in fixed-time traffic light signalization. However whereas in the fixed-time signalisation the green, amber and red periods are of fixed duration and are repeated in equal recurring cycles the same is not the case in traffic warden signalization. In human controlled operation, the recurring green time and cycle lengths are not constant, there is also the tendency for the method to become similar in operation to a vehicle-actuated signalization especially at an undersaturated intersection.

☐ ***Geometric Parameters***

The geometric parameters of the intersection and approaches were measured using a Total Station and results obtained are as shown in Table 1. The obtained geometric parameters are used as input in computing the saturation flow rates of the intersection approaches.

☐ ***Capacity computation***

The approach capacity is obtained from equations 1 and 2. The saturation flow rate (s_i) in equation 2 is obtained for each approach using the input values shown in Table 1 while the adjustment factors are obtained as given by HCM, 2000. Table 2 shows the computed saturation flow rates. The observed traffic flow (volume) and green time for each of the approaches are shown in Table 3. The green time (gt) used for capacity computation for each approach is obtained from Table 3 as the average of the green times recorded for each approach. The cycle length is 900 seconds (15 minutes) which is the period of observation. The capacity for each intersection is thereafter obtained by multiplying the saturation flow rate (s_i) with the ratio $(gt/cl)_i$. The computed capacities are shown in Table 4.

Table 1: Inventory data for Challenge Intersection

Approach	No of Approach Lanes	Approach Width (m)	Shoulder Width (m)	Overall Approach Width (m)	Median Width (m)	Approach Slope (%)
UBA	3	10.95	-	10.95	2.0	0.1
Post Office	3	10.70	-	10.70	2.0	0.1
Ahmadu Bello Way	2	7.30	-	7.30	2.0	4.24

Table 2: Input values for saturation flow rate computations

Intersection	Approach	S_o	Width	Shoulder	Slope	Width + Shoulder
Challenge	A Division	1800	10.95	-	0.12	10.95
	Post office	1800	10.70	-	-0.06	10.70
	Ahmadu Bello	1800	7.30	-	-4.22	7.30

N	f_w	N x f_w	f_{hv}	f_g	f_p	f_{bb}	f_a	f_{rt}	f_{lt}	s_i
3.00	1	3.00	0.97	1	0.95	1	0.9	1	1	4478
2.93	1	2.93	0.97	1	0.97	0.98	0.9	1	1	4379
2.00	1	2.00	0.98	1.02	0.91	0.96	0.9	1	1	2829

Table 3: Green time and traffic volume during each 15-minute observation period

Day		Sunday			Monday			Tuesday			Wednesday			Thursday			Friday			Saturday		
Approach		M	A	E	M	A	E	M	A	E	M	A	E	M	A	E	M	A	E	M	A	E
UBA	GREEN TIME (sec)	457.8	474	420.6	453	513	469	481	473	473	434	392	507	453	571	441	475	537	472.2	460.8	487.8	445.2
	VOL (veh/hr)	387	368	359	408	328	283	430	370	334	402	350	334	377	371	387	391	383	421	448	401	426
POST OFFICE	GREEN TIME (sec)	438	534	486	511	514	524	512	528	587	556	515	515	521	552	510	506	590	480	474	492	492
	VOL (veh/hr)	270	309	313	311	342	317	305	316	249	322	257	285	353	304	354	330	308	298	263	310	327
AHMADU BELLO	GREEN TIME (sec)	378	414	306	389	442	376	388	372	313	344	385	385	374	343	392	389	310	390	414	372	372
	VOL (veh/hr)	289	260	237	290	270	195	273	252	152	257	295	195	258	159	269	195	167	301	212	185	200

Table 4: Obtained capacities

Intersection	Approach	s_i	Avg Green time (sec)	Cycle length (sec)	Capacity (veh/hr/lane)
Challenge	A Division	4478	470.97	900.00	2343
	Post office	4379	515.15	900.00	2506
	Ahmadu Bello	2829	373.71	900.00	1175

Discussion

Although the intersection studied is traffic warden controlled and not fixed-time signalised the capacity model for fixed-time signalised intersection model has been successfully used to determine the capacity of the various approaches at the study location. The approach used in the study for computing intersection capacity at a traffic warden controlled intersection overcomes the difficulty encountered in using the manual method of delay survey where the stopped and non-stopping vehicles on an approach is counted (Box and Oppenlander, 1976) particularly when the queue length on an approach is long. The obtained capacities can be further used in models provided by HCM, 2000 in computing the average delay per vehicle at an intersection and the subsequent level of service (LOS) of the intersection.

CONCLUSIONS

The capacity model for fixed-time signalised intersection has been used to determine the capacity at a traffic warden controlled intersection. The obtained capacity can be further used to determine the LOS at the intersection. The approach used in the study for computing intersection capacity at a traffic warden controlled intersection overcomes the difficulty encountered in using the manual method of delay survey where the stopped and non-stopping vehicles on an approach is counted particularly when the queue length on an approach is long and is recommended for the determination of the capacity at traffic warden controlled intersections.

REFERENCES

[1.] *Adenle, J.A.: "Factors Militating Against Free Flow of Traffic in Metropolitan Lagos". in Transportation in National Development edited by Onakomaiya S.O. and Ekanem N.F. NISER, 1981*

[2.] *Akcelik, R.: "The Highway Capacity Manual Delay Formula for Signalised Intersections". ITE Journal 58(3), p 23-27, 1988.*

[3.] *Akgungor A. P. and Bullen A. G. R.: 'A New Delay Parameter for Variable Traffic Flows at Signalised Intersections'. Turkish Journ. Engr. Env. Sci 31. pp 61-70. 2007*

[4.] *Box P.C. and Oppenlander J.C.: Manual of Traffic Engineering Studies (4th Ed). U.S.A. Inst of Transportation Engineers Inc. 1976*

[5.] *Highway Capacity Manual: Highway Capacity Manual, Washington D.C., National Academy of Science. National Research Council Publication 1328, 2000*

[6.] *Ogden K.W.: 'Truck Movement and Access in Urban Areas'. Journal of Transportation Engineering. Vol. 117, No. 1 January/February 1991 PP. 71- 90. 1991*

[7.] *Ogunsanya A.A.: 'Traffic Congestion in an Urban Centre; The Case of Ilorin', Nigerian Geographical Journal Vol. 27 Nos. 1 & 2, 1984.*

[8.] *Okunlola N. O.: 'A Study of Traffic Operation on Major Arterials in Ilorin'. M.Eng. Thesis submitted to the Department of Civil Engineering, University of Ilorin, Ilorin, Nigeria. 2002*

[9.] *Papacostals C.S.A. & Prevedouros P. D.: Transportation Engineering & Planning (3rd Ed). U.S.A Prentice Hall, Inc. 2001.*

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