Capacity Evaluation Of Rotary Intersection In Kabul Afghanistan

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Abstract:** Traffic increasing and growth are the huge concern in all urban cities of Afghanistan. The increasing of population of Kabul city along with development and growth of the business and reconstruction in recently 2 decades is the major concern for the Traffic Department. Traffic department interested and try to design the road and Rotary Intersection with high capacity and level of performance to avoid the congestion in Rotary intersections and remove the Queue. The evaluating of capacity of Un-channelized Rotary intersection is very important in the management of traffic engineering. The overall capacity of the road is decrease in the rotary intersection compare to straight portion of the road because the speed is decrease in the rotary intersection and making the queue which polluted the environment and wasting time of passengers as well as increasing in use of oil. During the peak hour in AM & PM the condition become sever due to increment in traffic volume and reaching to double of normal traffic volume. Rotary Intersection are constructed for the purpose to remove Queue, stoppage, accident and removing the hazard in crossing of car from one direction or lane to another by allowing the vehicles in alternate pattern as well as for smooth and safe movement of traffic. The different variable which effect the capacity of the Rotary intersection were also considered like: flow of vehicle, Environmental features, Rotary intersection geometric Design and turning of vehicles which follow the Poisson distribution curve. In this paper, the main focus is on the evaluation of capacity of rotary intersection, avoid of congestion, safe movement of passengers and studies of those parameters which effect on capacity of Rotary to suggest and find the solution for these parameters.

***Keywords:** Rotary, Capacity, Un-signalized, Un-Channelized, Queue, Poisson distribution*

I. INTRODUCTION

A. BACKGROUND

Congestion is increased in Afghanistan day by day which worsts the traffic control and management in the Afghanistan and creating the problem mostly in the Kabul City which is the capital and has more than 5 million population as well as more than one million of vehicles which makes the congestion on the road and rotary intersection. The Kabul city is covered by the mountain and the river is crossing the heart of city and the weather condition is very good in comparison to other cities of Afghanistan and also there are more national and international NGO's and organization and people are coming from all over the Afghanistan and the world which causes rapid development of the population and vehicles as well as growth in traffic. Kabul city is the most congested city of the Afghanistan which has very poor and limited transit system such as KPBS (Kabul Public Bus system), ABTS (Alyousuf Bus Transport system). These two are the semi-public transport system and the other modes of transportation are the taxi, cars, and two wheelers; the un-presence of the transport

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system caused people to purchase their own cars which led the city to be congested on Road and intersections when crossing the intersection due to lack of the public transport system enough capacity is required on road and rotary intersection for safe journey of the vehicles and pedestrians. Baraki rotary is selected for evaluation of capacity which is having four legs connecting the Sarai Shamali, Taimani, Poly Technic University and the center of the Kabul city. The manual survey is performed for the data collection in peak hours of evening at 04:00 pm to 05:30 pm to determine the volume of traffic, flow at lanes and relative speed.

B. STUDY AREA

Area selected for the study is Baraki Rotary Intersection which is surrounded by the commercial and residential buildings shown in Figure 1.1. The traffic flow is varies in peak and non-peak hours. During the peak hours the maximum traffic volume is from center to Sarai Shamali and from Taimani to Poly Technics University and the traffic volumes are include the Taxi, private buses, Mazdas, cars and two wheelers.

Figure 1.1 Study Area in Kabul City

C. OBJECTIVES

The main objective of this case study is to evaluate the capacity of Rotary intersection which is includes the bellow points:

- ✓ Capacity Analysis of intersection.
- ✓ To Evaluate the Capacity of Barraki Rotary.
- ✓ To determine the factors and causes of Congestion.
- ✓ Solution generation for removal of congestion and for safe movement of vehicles at Barraki Rotary.

D. RESEARCH METHODOLOGY

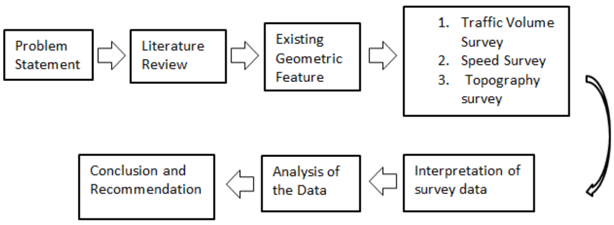

Figure 1.2

E. PROBLEM STATEMENT

The study is start on the Baraki un-channelized rotary intersection shown in Figure 1.1 the intersection has the congestion in peak hours and making the long queues which are controlled by Traffic police at present. The congestion are due to Rotary intersection is un-channelized and there is no marking on road to determine the path for vehicles through which turn and pass as well as control movement of the vehicles as shown in Figure 1.2.

II. LITERATURE REVIEW

To understand the purpose and scope of the research many previous studies relevant to the research have been studied which are done for the same purpose as mentioned bellow:

Miteshkumar N Damor and Harshad C Prajapati (2014)[4] *L.D. College of Engineering, Gujarat Technological University, Navrangpura, Ahmedabad* done "An Evaluation of Capacity of Roundabout" A Case Study of Aanjali Roundabout at Ahmedabad" and found by the formula the capacity of weaving sections for all 4 legs of intersections per hour as well as found that total number of vehicles entering the intersection are more than 3000 VPH; therefore, roundabout has not capacity of accommodating the volume of traffic safely and alternative should be adopted to accommodate the and regulate the traffic.

Jing Bie, Hong K. Lo and S. C. Wong (2010)[5] *the University of Hong Kong, Pokfulam Road, Hong Kong, China* "Capacity Evaluation of Multi-lane traffic roundabolut" they used the HCM (High way capacity manual) and Kimber models for analysis of the capacity of Multi lane roundabout and found that both turning proportions and drivers' lane usage within a roundabout substantialy impact on the capacity of roundabout.

Hideki NAKAMURA Associate Professor Department of Civil Engineering and Taiki MABUCHI Nagoya University Furo-cho, Chikusa-ka, Nagoya 464-8603, Japan (2007)[6] "Performance Evaluation of Roundabouts Considering Traffic Conflicts" has done the research and evaluate the performance of Roundabout considering the Traffic Conflict and found that Roundabouts are betters in comparison to the signalized intersection if the volumes are less than 600 VPH and the performance of roundabouts are decreasing by the difference of traffic volume to each approach increase as well as the performance of roundabout decrease with increasing of right turning.

Alpana jha Lecturer (Civil Engineering), Government Polytechnic, Ahmedabad, Gujarat (2014)[7] *"Capacity Evaluation of ISKON Intersection on Highway in Ahmedabad-A Case Study"* has been performed in India and found that the Capacity of intersection is less than demand of traffic and recommend that signalized condition should be improved as well as geometric condition and found that Volume to Capacity Ratio is greater than one which indicated the current geometric and signals cannot accommodate the critical flow.

Debasish Das M-tech Scholar, Civil Engineering Department, NIT Slichar, Assam-788010, India and Dr. M Ali Ahmed Professor, Civil Engineering Department, NIT Slichar, Assam-788010, India Performed "Performance Analysis of Rotary Intersection: Case study, Slichar, Assam" in India analyzed the four rotaries based on traffic flow and geometric features and found that those rotaries which are near to CBD

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(Central Business District) are more effected by flow of traffic and found that suitable distance from the CBD is 1500 m. within the radius of 1500 m the rotary intersection has poor performance and this is the reason that rotary not to be preferred at CBD of urban area.

A. EXISTING GEOMETRIC FEATURES

The Geometry of Rotary influenced the Capacity of rotary when the vehicles reached to rotary it decrease the speed for safe movement and crossing the rotary. The breath of the approach leg, deflection Angle of the approach road, curvature, wide of the Rotary Circle, wide of the Exit Road, Radius of the Rotary and radius of waving path are direct effecting on the capacity and speed of vehicles the more width of the rotary and exit road the less will be the congestion even no congestion so these all are influence on the capacity of rotary and speed of the vehicles. When driver reaches to the rotary they checking the conflict area as well as the conflict vehicles and the geometry of rotary and decide to cross the rotary on the speed when there is no conflict area and the deflection angle between his entrance and exit way is less so he decide to go and high speed to cross the rotary.

B. GEOMETRIC ELEMENTS

Well-designed rotary has less conflicted area and no congestion and the vehicles can cross the rotary without waiting or making short queue in peak hours the Geometric elements of the Rotary are: Circle Diameter, Island Diameter, Rotary number of legs, Splitter type, Width of entry road, Radius entry road, Deflection angle and entry path Curvature of road, Carriage width of Circulatory road, Number of lanes and angle between approach roads as shown in below figure.

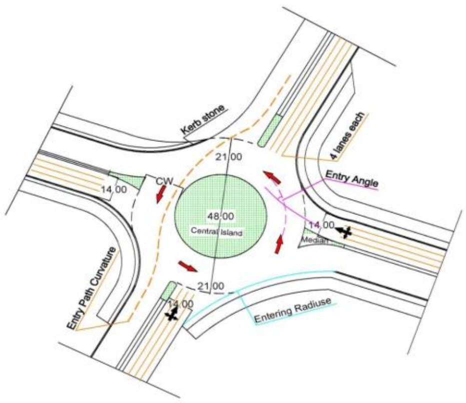

Figure 2.1: Geometric elements of the rotary

III. TRAFFIC VOLUME COUNT

The manual method used for traffic volume count which is done by technical engineers on site by counting all type of vehicles with their direction which is the accurate method for volume count and direction of the vehicles even it is cost consuming method and required more manpower to perform the survey. each road are surveyed in 7 days of the week to determine the peak hour of the week the survey data which are collected from site converted into PCU Per Hour as per IRC standard mentioned in (Traffic Engineering and Transportation Planning)[1] to found the maximum flow direction and peak hour. It was found that Maximum Number of Vehicles were passing through University was from Polytechnic University to Taimani in straight direction. From the data collected from site during the week and each hour of the day found that the peak day is the start day of the week (Saturday) which has the maximum volume of traffic and the peak hour calculated is from 04:00PM to 05:00 PM.

Count Hour	**Daily Total Volume in PCU**				
	Taimani	**Kabul City**	**polytechnic Universit**	**Sarai shamali**	Total
07-08am	1421.4	935.9	1040.8	1063.1	4461.2
08-09am	2105.4	1884.4	1762.8	2048.2	7800.8
09-10am	2172	1850	2012.3	1400.6	7434.9
10-11am	1711.5	1177.9	1239.1	1272	5400.5
11-12am	1092.4	915.2	1355.2	1230	4592.8
12-01pm	1195.5	1307.1	1245.6	1324.3	5072.5
01-02pm	1547	1479.3	1466	1540.7	6033
02-03pm	1745.6	1452.8	1779.4	1931.5	6909.3
03-04pm	2491.3	2477.4	2474.8	2204.1	9647.6
04-05pm	**2532**	**2908**	**2790**	**2325**	**10555**
05-06pm	2092	2444.4	2367.6	2073.9	8977.9
Total vol	20105.7	41566.6	44382.9	45825.1	76886

Table 3.1: Total Traffic Volume Converted in PCU

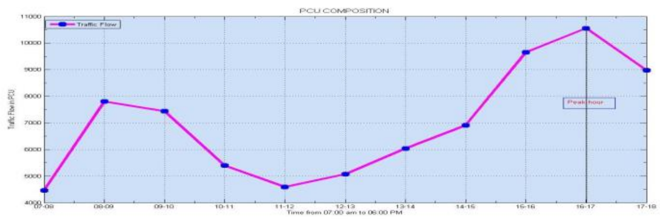

Figure 3.1: Daily Traffic Flow Chart

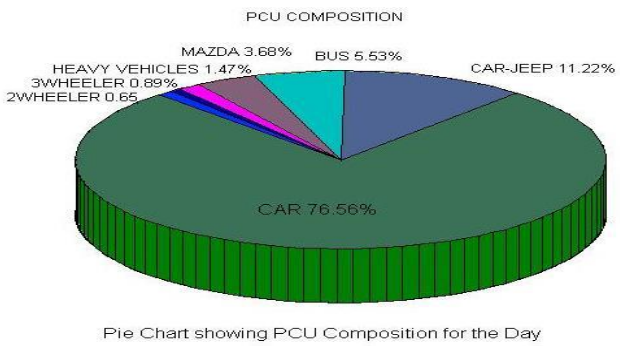

Figure 3.2: Daily Traffic Pie Chart

(PCU per hour)			
Leg To wards Sarai Shamali	Right side	Stright	Left side
	500	1233	592
Leg To wards Kabul City	Right side	Stright	Left side
	791	1621	496
Leg To wards	Right side	Stright	Left side

Taimani	435	1642	455
Leg To wards Polytechnic University	Right side	Stright	Left side
	476	1782	532

Table 3.2: Volume on PCU per hour

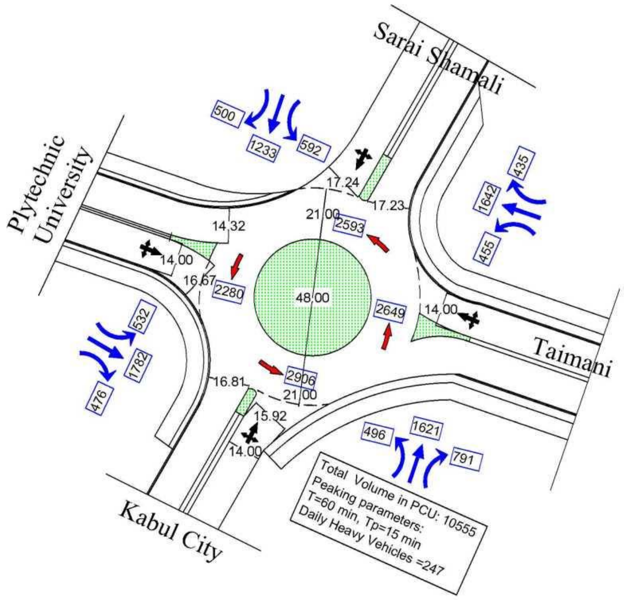

Figure 3.4: Flow movement of the vehicles per hour

IV. POISSON REGRESSION

For the probability of arrivals of vehicles in specific time interval when n is large and the value of p is small determining by passion distribution. Poisson distribution deal with random properties of the traffic and mostly deal with traffic. The number of heavy vehicles which arrives to the rotary in last 15 minutes of the peak hour is determined bellow.

Daily Heavey Vehicle Volume			
Taimani	Kabul City	Polytechnic University	Sarai Shamali
119	24	61	43
Heavey Vehicle During Peak hour			
Taimani	Kabul City	Polytechnic University	Sarai Shamali
22	0	11	3

Table 4.1: Heavy Vehicle Volume

No. of vehicles arriving in 15 sec interval	Observed Frequency (f)	Total Number of vehicles	Total time (observed frequency x 15)	Probability of vehicles arrivals in 15 sec
0	40	0	600	0.567414
1	13	13	195	0.321534
2	3	6	45	0.091101
3	2	6	30	0.017208
4	1	4	15	0.002437
5	1	5	15	0.000277
6 and over	0	0	0	0.000029
Total	60	34	900	1

Table 4.2: The probability of arrivals of heavy vehicles to the rotary

Poisson Regression used to determine the arrivals of discrete, random, independent vehicles which are assumed to follow a Poisson distribution the parameters for predicting the probability are as bellow:

Probability $P_{(r)} = (\lambda t)^r \times e^{-\lambda t}/r!$

$P_{(r)}$ = Probability of occurrence or arrivals of event or Vehicles r times in n trial

λ = Arrival Per unite time (one second) and

λ = Total Number of Vehicles during the observation / Total time of observation

t = Is the time interval in which probability of the arrivals is to be calculated

r = is a discrete variable representing the number of event or Vehicles over a period of time t.

A. ANALYSIS OF SPEED DATA

The vehicles speed data collected on each road or leg of Rotary which are entering to the rotary as per the PCU Composition the four wheeler LCV are the major and high volume so the speed data are collected for the four wheeler LCV and converted to the class interval which is calculated and converted as per bellow formula:

i = Range/1+3.222logN

i = Speed Class Interval

Range = Difference between the Maximum Speed and Minimum Speed

N = is the Observation Number

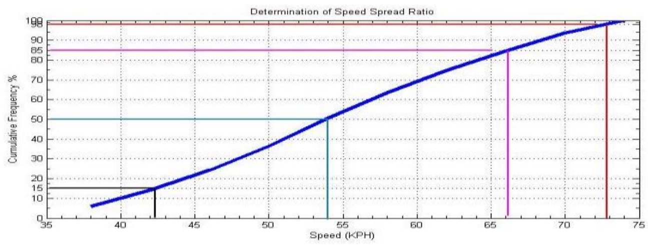

Figure 4.5: Determination of Speed Spread ratio and different percentile speed

The speed studies was performed on the intersection to determine the effect on the rotary and find the different percentile speed as the above graph shows the percentile speed is as bellow:

- ✓ 98% percentile speed or Geometric design speed is computed 73 KPH for the leg of the rotary.
- ✓ 85% percentile speed or speed limit is 66 KPH.
- ✓ 50% percentile speed or mean speed is 54 KPH.
- ✓ 15% percentile speed or low speed is 42 KPH.

From above computation of speed are clearly visible that during non-congestion period the speed on which the vehicles are approaching to rotary is not less than the speed for which the legs of rotary are designed and speed are not effecting the capacity of the rotary as per above computing of speed in the mentioned rotary intersection.

B. CAPACITY ANALYSIS

To determine the capacity of rotary it should analysis for individual leg of rotary as per HCM (Highway Capacity Manual). In this paper we analysis the capacity of rotary as per HCM and evaluate the capacity of individual legs of rotary entering to the rotary based on arrivals of vehicles to the rotary

Data available and collected from site to evaluate the Capacity of the Barraki Rotary:

- ✓ Heavy vehicles percentage for north side (Taimani) and south side (Polytechnic University) are 1.5%
- ✓ Heavy vehicles percentage for east side (Kabul City) and west side (Sarai shamali) are 0.13%.
- ✓ Peak hour factor =0.95
- ✓ Pedestrian activity Negligible.
- ✓ Volume and lane configurations as shown in bellow Figure

Land use specified for the northbound and southbound approaches:

The percentage flow in right lane is 29%, the percentage flow in middle-right lane is 26%, the percentage flow in middle-left lane is 22% and the percentage flow in left lane is 23%.

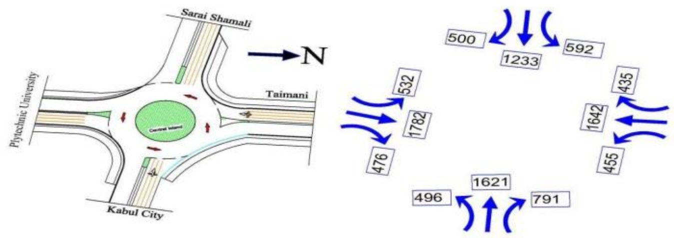

Figure 4.6: Flow movement of vehicles in peak hour

STEP1: CONVERT MOVEMENT DEMAND VOLUMES TO FLOW RATES

All the Turning-movement demand volume collected from site is converted to demand flow rate by dividing the peak hour factor as bellow for Northbound, Southbound, Eastbound and Westbound:

$$V_{NBL}=\frac{VNBL}{PHF}=\frac{532}{0.95}=560\ veh/h,$$
$$V_{NBR}=\frac{VNBR}{PHF}=\frac{476}{0.95}=502\ veh/h,$$
$$V_{NBS}=\frac{VNBS}{PHF}=\frac{1782}{0.95}=1876\ veh/h$$
$$V_{SBL}=\frac{VSBL}{PHF}=\frac{455}{0.95}=479\ veh/h,$$
$$V_{SBR}=\frac{VSBR}{PHF}=\frac{435}{0.95}=458\ veh/h,$$
$$V_{SBS}=\frac{VSBR}{PHF}=\frac{1642}{0.95}=1729\ veh/h$$
$$V_{EBL}=\frac{VEBL}{PHF}=\frac{592}{0.95}=624\ veh/h,$$
$$V_{EBR}=\frac{VEBR}{PHF}=\frac{500}{0.95}=527\ veh/h,$$
$$V_{EBS}=\frac{VEBS}{PHF}=\frac{1233}{0.95}=1298\ veh/h$$
$$V_{WBL}=\frac{VWBL}{PHF}=\frac{496}{0.95}=523\ veh/h,$$
$$V_{WBR}=\frac{VWBR}{PHF}=\frac{791}{0.95}=833\ veh/h,$$
$$V_{WBS}=\frac{VWBS}{PHF}=\frac{1621}{0.95}=1707\ veh/h$$

STEP 2: ADJUST FLOW RATES FOR HEAVY VEHICLES

For Northbound and southbound

$$fHV=\frac{1}{1+Pr(Et-1)}=\frac{1}{1+0.015(2-1)}=0.985$$

Et= Passenger car equivalent for heavy vehicles.

For the East and West bounds movements are:

$$fHV=\frac{1}{1+Pr(Et-1)}=\frac{1}{1+0.0013(2-1)}=0.998$$

Adjusted Flow Rates for all Movements, accounting for step1 and 2, are therefore as bellows:

$$V_{NBL,pce}=\frac{VNBL}{fHV}=\frac{560}{0.985}=569\ pc/h,$$
$$V_{NBR,pce}=\frac{VNBR}{fHF}=\frac{502}{0.985}=510\ pc/h,$$
$$V_{NBS,pce}=\frac{VNBS}{fHF}=\frac{1876}{0.985}=1905\ pc/h$$
$$V_{SBL,pce}=\frac{VSBL}{fHV}=\frac{479}{0.985}=487\ pc/h,$$
$$V_{SBR,pce}=\frac{VSBR}{fHF}=\frac{458}{0.985}=465\ pc/h,$$
$$V_{SBS,pce}=\frac{VSBS}{fHF}=\frac{1729}{0.985}=1756\ pc/h$$
$$V_{EBL,pce}=\frac{VEBL}{fHV}=\frac{624}{0.998}=626\ pc/h,$$
$$V_{EBR,pce}=\frac{VEBR}{fHV}=\frac{527}{0.998}=529\ pc/h,$$
$$V_{EBS,pce}=\frac{VEBS}{fHV}=\frac{1298}{0.998}=1300\ pc/h$$
$$V_{WBL,pce}=\frac{VWBL}{fHV}=\frac{523}{0.998}=525\ pc/h,$$
$$V_{WBR,pce}=\frac{VWBR}{fHV}=\frac{833}{0.998}=835\ pc/h,$$
$$V_{WBS,pce}=\frac{1707}{0.998}=1711\ pc/h$$

STEP 3: DETERMINE CIRCULATING AND EXISTING FLOW RATES

To determine the Circulating and Existing Flow Rates only Circulating Flow is calculating for each leg.

For the North leg (southbound entry), For the South leg (northbound entry), east and west as calculating bellow:

$V_{C,NB,PCE}=V_{EBU,PCE}+V_{SBU,PCE}+V_{WBU,PCE}+V_{EBT,PCE}+V_{EBL,PCE}+V_{SBL,PCE}$, $V_{C,SB}$=0+0+0+1711+525+569=2805 pc/h

$V_{C,SB,PCE}=V_{NBU,PCE}+V_{EBU,PCE}+V_{WBU,PCE}+V_{WBT,PCE}+V_{WBL,PCE}+V_{NBL}$, $V_{C,SB,PCE}$=0+0+0+1300+626+487=2413 pc/h

$V_{C,EB,PCE}=V_{NBU,PCE}+V_{WBU,PCE}+V_{SBU,PCE}+V_{SBT,PCE}+V_{SBL,PCE}+V_{WBL}$, $V_{C,EB,PCE}$=0+0+0+1905+569+626=3100 pc/h

$V_{C,WB,PCE}=V_{NBU,PCE}+V_{EBU,PCE}+V_{SBU,PCE}+V_{NBT,PCE}+V_{NBL,PCE}+V_{EBL}$, $V_{C,EB,PCE}$=0+0+0+1756+487+525=2768 pc/h

STEP 4: DETERMINE ENTRY FLOW RATES BY LANE

To calculate the entry flow rates so simply we summing the flow of vehicles entering to rotary from each legs and we can achieve the four entry flow rates as we have four leg rotary intersection as bellow"

Northbound: the rotary has four legs and four lanes each leg. The northbound has four lanes shared right-turn, through and left turn; one lane only for right turn, two lanes for through and one lane for left turn only. The flow rate in each lane is as bellow:

Right turn flow is = 510 pc/h, through =1905 pc/h, and the left turn flow is= 569 pc/h. A checked is needed to determine whether any lanes are in effect and de facto theses checks are as bellows:

Right lane: The right turn flow rates, 510 pc/h, is less than the sum of the though and right turn flow rates, 1905+569=2474 pc/h. therefore, some of the though volume is assumed to use the right lane and no de facto right turn condition is present.

Left lane: The left turn flow rate, 569 pc/h is less than the sum of the though and right turn flow rates, 1905+510=2415 pc/hl; therefore, some of the through volume is assumed to use the left lane, and no de facto left-turn lane condition is present.

The total entry flow (510+1905+569=2984 pc/h) is therefore distributed over the four lanes, with flow biased to the right lane using the lane use Factor identification previously:

Right lane: (2984)(0.29)=866pc/h , Middle two lanes: (2984)(0.26)=776 pc/h

Middle two lanes: (2984)(0.22)=656 pc/h, Left lane: (2984)(0.23)=686 pc/h

Southbound: The southbound also has four lanes shared right-turn, through and left turn; one lane only for right turn, two lanes for through and one lane for left turn only. The flow rate in each lane is as bellow:

Right turn flow is = 465 pc/h, through =1756 pc/h, and the left turn flow is= 487 pc/h. A checked is needed to determine whether any lanes are in effect and de facto theses checks are as bellows:

Right lane: The right turn flow rates, 465 pc/h, is less than the sum of the though and right turn flow rates, 1756+487=2243 pc/h. therefore, some of the though volume is assumed to use the right lane and no de facto right turn condition is present.

Left lane: The left turn flow rate, 487 pc/h is less than the sum of the though and right turn flow rates, 1756+465=2221 pc/hl; therefore, some of the through volume is assumed to use the left lane, and no de facto left-turn lane condition is present.

The total entry flow (465+1756+487=2708 pc/h) is therefore distributed over the four lanes, with flow biased to the right lane using the lane use Factor identification previously:

Right lane: (2708)(0.29)=785pc/h , Middle two lanes: (2708)(0.26)=704 pc/h

Middle two lanes: (2708)(0.22)=596 pc/h, Left lane: (2708)(0.23)=623 pc/h

Eastbound: The Eastbound also has four lanes shared right-turn, through and left turn; one lane only for right turn, two lanes for through and one lane for left turn only. The flow rate in each lane is as bellow:

Right turn flow is = 529 pc/h, through =1300 pc/h, and the left turn flow is= 626 pc/h. A checked is needed to determine whether any lanes are in effect and de facto theses checks are as bellows:

Right lane: The right turn flow rates, 529 pc/h, is less than the sum of the though and right turn flow rates, 1300+626=1926 pc/h; Therefore, some of the though volume is assumed to use the right lane and no de facto right turn condition is present.

Left lane: The left turn flow rate, 626 pc/h even if is less than the sum of the though and right turn flow rates, 1300+529=1829 pc/hl, but the flow is more than the Left lane: (2455)(0.23)=565 pc/h therefore, some of the left volume is assumed to use the through lane, and no de facto through lane condition is present.

The total entry flow (529+1300+626=2455 pc/h) is therefore distributed over the four lanes, with flow biased to the right lane using the lane use Factor identification previously:

Right lane: (2455)(0.29)=712pc/h , Middle two lanes: (2455)(0.26)=638 pc/h

Middle two lanes: (2455)(0.22)=540 pc/h, Left lane: (2455)(0.23)=565 pc/h

Westbound: The westbound also has four lanes shared right-turn, through and left turn; one lane only for right turn, two lanes for through and one lane for left turn only. The flow rate in each lane is as bellow:

Right turn flow is = 835 pc/h, through =1711 pc/h, and the left turn flow is= 525 pc/h. A checked is needed to determine whether any lanes are in effect and de facto theses checks are as bellows:

Right lane: The right turn flow rates, 835 pc/h, is less than the sum of the though and right turn flow rates, 1711+525=2236 pc/h. therefore, some of the though volume is assumed to use the right lane and no de facto right turn condition is present.

Left lane: The left turn flow rate, 525 pc/h is less than the sum of the though and right turn flow rates, 1711+835=2546 pc/hl; therefore, some of the through volume is assumed to use the left lane, and no de facto left-turn lane condition is present.

The total entry flow (835+1711+525=3071 pc/h) is therefore distributed over the four lanes, with flow biased to the right lane using the lane use Factor identification previously:

Right lane: (3071)(0.29)=891pc/h , Middle two lanes: (3071)(0.26)=798 pc/h

Middle two lanes: (3071)(0.22)=676 pc/h, Left lane: (3071)(0.23)=706 pc/h

STEP 5: DETERMINE THE CAPACITY OF EACH ENTRY LANE AND BYPASS LANE AS APPROPRIATE IN PASSENGER CAR EQUIVALENTS

Northbound: The northbound entry is a four lane entry and opposed by circulating lane equation for right lane, middle lanes and left lane as per HCM 2010 equations are as bellow:

$C_{PCE,NB,R}=1130e^{(-0.7X\ 0.001)(2413)}=209$ pc/h, $C_{PCE,NB,T}=185$ pc/h, $C_{PCE,NB,T}=185$ pc/h, $C_{PCE,NB,L}=185$ pc/h

Southbound: The southbound entry is a four lane entry and opposed by circulating lane equation for right lane, middle lanes and left lane as per HCM 2010 equations are as bellow:

$C_{PCE,SB,R}=1130e^{(-0.7X\ 0.001)(2805)}=159$ pc/h, $C_{PCE,SB,T}=138$pc/h, $C_{PCE,SB,T}=138$ pc/h, $C_{PCE,SB,L}=138$ pc/h

Eastbound: The eastbound entry is a four lane entry and opposed by circulating lane equation for right lane, middle lanes and left lane as per HCM 2010 equations are as bellow:

$C_{PCE,EB,R}=1130e^{(-0.7X\ 0.001)(2786)}=161$ pc/h, $C_{PCE,EB,T}=140$pc/h, $C_{PCE,EB,T}=140$ pc/h, $C_{PCE,EB,L}=140$ pc/h

Westbound: The westbound entry is a four lane entry and opposed by circulating lane equation for right lane, middle lanes and left lane as per HCM 2010 equations are as bellow:

$C_{PCE,WB,R}$=1130e$^{(-0.7X}$ $^{0.001)(3100)}$=129 pc/h, $C_{PCE,WB,T}$=110pc/h, $C_{PCE,WB,T}$=110 pc/h, $C_{PCE,WB,L}$=110 pc/h

STEP 6: DETERMINE PEDESTRIAN IMPEDANCE TO VEHICLES

As the pedestrian are negligible so no impedance calculation are required.

STEP 7: CONVERT LANE FLOW RATES AND CAPACITIES INTO VEHICLES PER HOUR

Lane Capacity is converted to vehicles and first the heavy vehicle adjustment factor for the lane is determining than multiplying it by the capacity in passenger car equivalent. The turning movement of northbound and southbound entries have the same f_{HV}, and each lanes on the northbound and southbound entries have the same f_{HV}=0.985.

$C_{NB,R}$=$C_{Pce,NB,R}$ $f_{HV,e,EB}$=(209)(0.985)=206 veh/h, $C_{NB,T}$= 182 veh/h, $C_{NB,T}$= 182 veh/h, $C_{NB,L}$=182 veh/h

$C_{SB,R}$= 157 veh/h, $C_{SB,T}$= 136 veh/h, $C_{SB,T}$ =136 veh/h, $C_{SB,L}$= 136 veh/h

The turning movement of eastbound and westbound entries have the same f_{HV}, and each lanes on the eastbound and westbound entries have the same f_{HV}=0.998.

$C_{EB,R}$=$C_{Pce,EB,R}$ $f_{HV,e,EB}$=(161)(0.998)=160 veh/h, $C_{EB,T}$= 139 veh/h, $C_{EB,T}$= 139 veh/h, $C_{EB,L}$= 139 veh/h

$C_{WB,R}$ =128 veh/h, $C_{WB,T}$ =109 veh/h, $C_{WB,T}$ =109 veh/h, $C_{WB,L}$= 109 veh/h

Calculation for the entry flow rates for North, South, East and West bound are as bellows:

$V_{NB,R}$=$V_{Pce,NB,R}$ $f_{HV,e,NB}$=(866)(0.985)=853 veh/h, $V_{NB,T}$=764 veh/h, $V_{NB,T}$ =646 veh/h, $V_{NB,L}$= 676 veh/h

$V_{SB,R}$=$V_{Pce,SB,R}$ $f_{HV,e,SB}$=(785)(0.985)=773 veh/h, $V_{SB,T}$=693 veh/h, $V_{SB,T}$= 587 veh/h, $V_{SB,L}$=614 veh/h

$V_{EB,R}$=$V_{Pce,EB,R}$ $f_{HV,e,EB}$=(712)(0.998)=710 veh/h, $V_{EB,T}$= 636 veh/h, $V_{EB,T}$= 538 veh/h, $V_{EB,L}$= 563 veh/h

$V_{WB,R}$=$V_{Pce,WB,R}$ $f_{HV,e,WB}$=(891)(0.998)=889 veh/h, $V_{WB,T}$= 796 veh/h, $V_{WB,T}$= 674 veh/h, $V_{WB,L}$= 704 veh/h

STEP 8: COMPUTE THE VOLUME-TO-CAPACITY RATIO FOR EACH LANE

Northbound: $X_{NB,R}$=$V_{NB,R}$/$C_{NB,R}$=853/752=1.13, $X_{NB,R}$=$V_{NB,T}$/$C_{NB,T}$=764/752=1.01, $X_{NB,R}$=0.90

Southbound: $X_{SB,R}$=$V_{SB,R}$/$C_{SB,R}$=773/565=1.36, $X_{SB,R}$=$V_{SB,T}$/$C_{SB,T}$=693/565=1.22, $X_{SB,R}$ =1.08

Eastbound: $X_{EB,R}$=$V_{EB,R}$/$C_{EB,R}$=710/577=1.23, $X_{EB,R}$=$V_{EB,T}$/$C_{EB,T}$=636/577=1.10, $X_{EB,R}$= 0.97

Westbound: $X_{WB,R}$=$V_{WB,R}$/$C_{WB,R}$=889/455=1.95, $X_{WB,R}$=$V_{WB,T}$/$C_{WB,T}$=796/455=1.75, $X_{WB,R}$=1.54

STEP 9: COMPUTE THE AVERAGE CONTROL DELAY FOR EACH LANE

The control delay for the northbound entry lane is computed as bellow:

$$d_{NBR}=\frac{3600}{752}+900(0.25)\left[\frac{853}{752}-1+\left(\left(\frac{853}{752}-1\right)^2+\frac{\left(\frac{3600}{752}\right)\frac{853}{752}}{450(0.25)}\right)^{0.5}\right]+5\times\min\left[\frac{853}{752},1\right]$$

=42 s/veh, d_{NBT}= 39.86s/veh

d_{NBT}=30.81 s/veh, d_{NBL}=36.07 s/veh and Also for the southbound, eastbound and westbound are as bellow:

$d_{SB,R}$=49.59 s/veh, $d_{SB,T}$=44 s/veh, $d_{SB,T}$=37.65 s/veh, $d_{SB,L}$=39.39 s/veh, $d_{EB,R}$=44.3 s/veh, $d_{EB,T}$= 41.8s/veh, $d_{EB,T}$=36.15 s/veh, $d_{EB,L}$=36.5 s/veh, $d_{WB,R}$=63.2 s/veh, $d_{WB,T}$=54.65 s/veh, $d_{WB,T}$=51.3 s/veh, $d_{WB,L}$=51.93 s/veh,

STEP 10: DETERMINE LOS FOR EACH LANE ON EACH APPROACH

On the basis of HCM 2010 the LOS for each lane is determined as bellow in the sequence of Lane, control delay on S/veh, and LOS Respectively:

Lane	C Delay (s/veh)	LOS
Northbound R lane	42	E
Northbound T lane	39.86	E
Northbound T lane	30.81	D
Northbound L lane	36.07	E
Southbound R lane	49.59	E
Southbound T lane	44	E
Southbound T lane	37.65	E
Southbound L lane	39.39	E
Eastbound R lane	44.3	E
Eastbound T lane	41.8	E
Eastbound T lane	36.15	E
Eastbound L lane	36.5	E
Westbound R lane	63.2	F
Westbound T lane	54.65	F
Westbound T lane	51.3	F
Westbound L lane	51.93	F

STEP 11: COMPUTE THE AVERAGE CONTROL DELAY AND DETERMINE LOS FOR EACH APPROACH AND THE ROUNDABOUT AS A WHOLE

The Control Delay for the approaches are as bellow:

$$d_{NB}=\frac{(42)(853)+(39.86)(764)+(30.81)(646)+(36.07)(676)}{853+764+646+676}=37.62$$

s/veh, d_{SB}=43.16 s/veh, d_{EB} = 40.06 s/veh

d_{WB}=55.76 s/veh. And the LOS of above Approaches are LOS E, LOS E, LOS E and LOS F

Control Delay for Intersection is as bellow:

$$d_{Intersection}=\frac{(37.62)(2939)+(43.16)(2667)+(40.06)(2447)+(55.76)(3063)}{2939+2667+2447+3063}=44.48$$

s/veh

The LOS of Intersection as per HCM Exhibit 21-1 is LOS E.

V. CONCLUSION

The Capacity of Rotary have analyzed and found that The South and East bounds (North and West Legs) have The LOS of D with a delay that can be solved by the signalizing of the rotary and channelizing. Currently the rotary have been controlling by traffic police and all traffic have not been following the traffic rule so by designing and installing of signal and proper used can improve the capacity of the rotary and LOS of the legs. Secondly current traffic volumes are 10555 PCU at peak hour so the rotary should channelize which can further improve the North and west legs of the rotary. The North and west bounds (south and east legs) are have the LOS E and F respectively which is affected the whole rotary LOS and capacity so below are the solution for the removing of congestion and increasing the whole rotary capacity:

- ✓ Channelize the rotary.
- ✓ Signal design should perform based on the volumes of traffic enter to rotary from each legs of the rotary.

One extra lane should add around the rotary inner circle as the inner circle of the rotary is 48 m so one lane should added around the rotary to increase the overall capacity of the rotary and based on computation it increase 10% capacity of the circulating flow volume and the delay time is decreasing 25% in the west leg so the total lanes around the rotary become 7 and the inner circle diameter decrease from 48m to 41 m.

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