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EFFECTS OF RAINFALL ON CONTROL DELAY AND QUEUE AT MULTILANE ROUNDABOUT

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ABSTRACT

The main thrust of the study is to investigate the extent of delay induced by rainfall at the roundabouts. Traffic flows at roundabout are continuous in one direction around a central island where entry flows yield to circulating flows. Based on the hypothesis that, rainfall will increase roundabout entry delay, 'with and without' rainfall studies were carried out at selected roundabouts in Durban, South Africa. Entry and circulating traffic flow data as well as geometric data were collected continuously at three selected sites during rainfall and dry weather conditions. Three classes of rainfall intensity were used: light rainfall with intensity < 2.5mm/h, moderate rainfall with intensity 2.5 – 10mm/h and heavy rainfall with intensity 10 – 50mm/h. Results show that entry delays increased between 11% and 22% during rainy conditions. The study concluded that heavy rainfall has a significant impact on delays and queues at roundabouts. The delay is not responsive to light and moderate rainfall intensity.

Keywords: delay, rainfall, roundabout, capacity, flows

1. INTRODUCTION

Roundabout is an intersection where traffic flows almost continuously in one direction around a central island. It works on a simple principle of giving way to circulating traffic flows when entering the intersection. Traffic flow exiting the roundabout comes from a singular direction. It is classified into mini and conventional roundabout depending on the size, location, designed speed and capacity. Vehicles entering a roundabout will experience delays because of the give-way rule and the geometric design of the roundabout. However, geometric delays are often reduced with the introduction of flare lane. Entry width and sharpness of flare are the most important determinants of capacity according to United Kingdom highway agency (TD 16/07, 2007). The size of the circulating width determines the speed at which drivers travel on the roundabout. The delay is a key performance measure of the roundabout. While delays associated with geometric design can be reduced with geometric adjustments, delays and queues triggered by rainfall cannot be reduced so easily. Although the yield rule holds at all times, both circulating and entering vehicles at roundabouts are affected by poor visibility, anxiety, discomfort and stress during rainfall. The aim of this paper is to investigate the extent of entry delay at roundabouts caused by rainy conditions. Rainfalls impair visibility of drivers irrespective of the intensity. (Ben-Edigbe *et al*., 2013). Rainfalls reduce the pavement friction due to precipitation (Mashros et al., 2014). The key objectives are to estimate and compare entry delay at roundabouts during dry and rainy conditions. Drivers approaching a roundabout must reduce speed to accommodate for deft movements and vehicle interaction at the roundabout. The size of the inscribed circle affects the radius of the driver's path, which in turn influence the operating speed on the roundabout. The British (Kimber, 1980), French (Guichet, 1997), and German (Brilon *et al*., 1997) analytical procedures are based on empirical relationships that directly relate capacity to both traffic characteristics and roundabout geometry. The British empirical relationships reveal that small sub-lane changes in the geometric parameters produce significant changes in capacity. Inscribed circle diameter, the entry width, the approach half width, the entry radius, and the sharpness of the flare are used to define the performance of a roundabout. The sharpness of the flare, S, is a measure of the rate at which the extra width is developed in the entry flare. Large values of S correspond to short, severe flares, and small values of S correspond to long, gradual flares (Kimber, 1980). The results of the extensive empirical British research indicate that approach half width, entry width, average effective flare length and entry angle have the most significant effect on entry capacity. Based on the hypothesis that, rainfall will increase entry delay multilane roundabout, the remainder of this paper is divided four sections; the immediate section is the literature review, section 3 is on materials and methodology, and section 4 is the findings and discussion. In section 5 conclusions are drawn.

2. LITERATURE REVIEW

Durban is the largest city in the South African province of KwaZulu-Natal. After Johannesburg, the Durban Metropolitan Area ranks second among the most populous urban areas in South Africa. Durban has the busiest port in South Africa and often seen as one of the major centres of tourism in South Africa. Durban and its suburbs are hilly, except for locations around the central business district and the harbour. The metropolitan land area of 2,292m^2 is comparatively larger than other South African cities. Rainfalls greater than 0.1mm/h begin in November, ending in March. Roundabouts in South Africa are often referred to as ‘traffic circles’. There are two types of traffic circles: a mini-circle and a roundabout. The rules are different for each kind of traffic circle. At a mini-circle, there is a small island hump in the middle of the intersection that the driver must go around. Mini-circles have an inscribed diameter of 25 m or less, and an inner diameter of around 2 to 4 m (DOT, 2005). The central island is often painted or slightly raised to allow vehicles to drive over it. As shown below in figure 1, a roundabout has a large circle that drivers must drive around in a clockwise direction, giving way to any circulating vehicle. Typically, it has an inscribed diameter of 26 m or greater, tracking width of 7.5 m or wider, as these are the minimum dimensions required to cater for large trucks. Roundabouts larger than the minimum are used to increase capacity. Notwithstanding, the ‘give way’ rule at roundabout will indeed induce delays and queues at the entry of a roundabout.

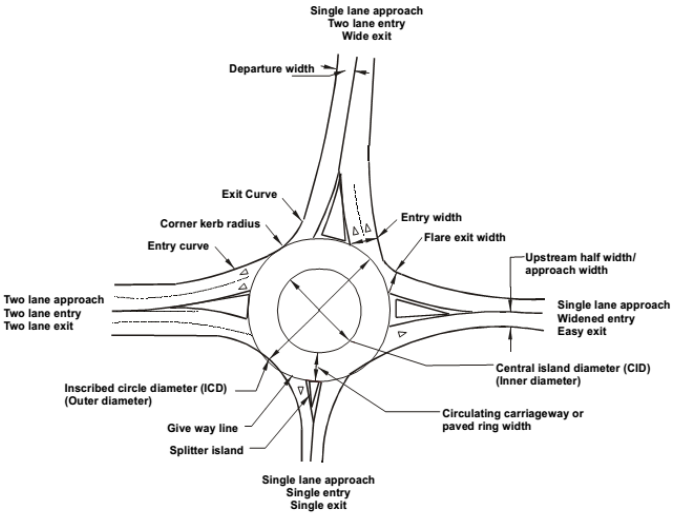

Figure 1: Typical roundabout layout in South Africa

2.1 Delays and queues at the roundabout

Three performance measures (delay, queue and degree of saturation) are typically used to estimate the performance of a given roundabout design. Each measure provides a unique perspective on the quality of service at the roundabout under observation. However, roundabout entry capacity estimate is needed before the delay, queue and degree of saturation measure can be computed. The delay is excess travel time experienced by drivers beyond what would reasonably be expected (Ben-Edigbe *et al*., 2013, Al-Omari et al., 2004). At roundabouts, there are two types of delays; control and geometric. Control delay experienced by drivers at an intersection due to movements at slower speeds and stops on entry approaches to the roundabout (Rodegerdts, 2010, HCM, 2010). Geometric delays are caused by the alignment of the lane or the path taken by the vehicle through the roundabout. It can be argued that control delay is defective if geometric delay is not fused into the control delay model equation. In previous studies, (Akcelic and Troutbcek 1991), (Kimber and Hollis 1980) and (Centre dÉtude des Transport Urbains 1988) delay have been presented as a function of gap acceptance. Although not the focus of this paper, the degree of saturation is the ratio of the demand entry flow to the entry capacity of the roundabout. While there are no absolute standards for the degree of saturation, 0.85 has often been used in previous studies as performance threshold. When the degree of saturation exceeds this range, the operation of the roundabout will likely deteriorate rapidly, particularly over short periods of time. Queues may form and delay begins to increase exponentially. Control delay is the time that a driver spends queuing and then waiting for an acceptable gap in the circulating flow while at the front of the queue. The formula for computing this delay is given in Equation 1.

[1] $$d = \frac{3600}{Qe} + 900T\left[x - 1 + \sqrt{(x-1)^2 + \frac{\left(\frac{3600}{Qe}\right)x}{450T}}\right] + 5$$

Queue length is necessary when assessing the adequacy of the geometric design of the roundabout approaches. It is equivalent to the vehicle-hours of delay per hour on an approach. The average queue length (L) can be computed with Little's rule (Little, 1961), as shown in Equation 2 or HCM 2010 recommended Equation 3:

[2] $$L = v \cdot d / 3600$$

Where: v= entry flow, veh/h; d= average delay, s/veh

[3] $$\boldsymbol{Q_{95} = 900T\left[x - 1 + \sqrt{(x-1)^2 + \frac{\left(\frac{3600}{Qe}\right)x}{150T}}\right]\left(\frac{Qe}{3600}\right)}$$

Where;

d = average control delay (s/veh),
T = the time period, usually 0.25 h,
Qe = entry capacity of the subject lane (veh/h),
x = degree of saturation of the subject lane
Q_{95} = the 95th percentile queue (veh)

2.2 Entry capacity at roundabout

Roundabout capacity can be defined as the maximum sustainable flow rate that can be achieved during a specified time period under prevailing road, traffic and control conditions. Roundabout entry capacity is often computed based on gap acceptance, empirical and design methods. The empirical approach is of interest to this paper because is a technique that considers the geometry parameters of the roundabout. Based on the British model (Kimber 1979) Equation 4 can be employed to compute entry capacity and Equation 5 used as the correction factor. According to

the British model, equation 5 is valid provided entry angle ($\emptyset$) is between 10^o and 60^o and radius is between 6m and 100m (Kimber 1979).

[4] $$\boldsymbol{Q_e = k(F - f_c Q_c)}$$

[5] $$\boldsymbol{k = 1 - 0.00347(\emptyset - 30) - 0.978\left(\frac{1}{r} - 0.05\right)}$$

Where,

Q_e= Entry Capacity (pcu/h); Q_c = Circulating Flow (pcu/h),
F = the intercept at Q_E (maximum entry flow when circulating flow is at zero);
f_c = the slope of the linear relationship;
$\emptyset$ = entry angle (^{o}), r = the entry radius;

As mention earlier in this paper, delay and queue computations depend on entry capacity estimation. Since entry capacity estimation has been shown in equations 4 and 5; then the entry capacity equation 4 can be fussed into equations 1 and 3 by replacing the entry capacity. The resulting delay equation is shown in equation 6 and 7.

[6] $$d = \frac{3600}{k(F - f_c Q_c)} + 900T\left[\left(\frac{q_E}{Q_E} - 1\right) + \sqrt{(x-1)^2 + \frac{\left(\frac{3600}{k(F - f_c Q_c)}\right)\left(\frac{q_E}{Q_E}\right)}{450T}}\right] + 5$$

[7] $$Q_{95} = 900T\left[\left(\frac{q_E}{Q_E} - 1\right) + \sqrt{\left(\frac{q_E}{Q_E} - 1\right)^2 + \frac{\left(\frac{3600}{k(F - f_c Q_c)}\right)\left(\frac{q_E}{Q_E}\right)}{150T}}\right]\frac{k(F - f_c Q_c)}{3600}$$

3. MATERIALS AND METHODOLOGY

Three standard roundabouts were selected in Durban for this rainfall impact study. Surveyed roundabouts are; Site 01 – Armstrong roundabout, Site 02 – Umghlanga Rock – Douglas Saunders roundabout and Site 03 - Millenium – Jubilee roundabout. The selection of the roundabouts was based on proximity to rain gauges because one of the key parameters to be considered was rainfall intensity. Rainfall was divided into three intensity classes; light ($i < 2.5$mm/hr), moderate ($2.5 \leq i < 10$ mm/hr) and heavy ($10 \leq i < 50$ mm/hr). Very heavy rainfall ($i > 50$mm/hr) was not considered because of excessive drag forces, ponding, aquaplaning and other factors associated with violent rainfall. As shown below in figure 2, automatic traffic counter (ATC) was used to collect traffic volume, headway, type of vehicle and speed were collected continuously for six weeks during the rainy season at entry and circulating widths of the selected roundabouts. Off-peak traffic data were used for the study in order to separate the effect of peak traffic flow from rainfall effect.

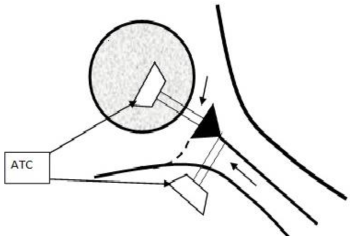

Figure 2: Typical site layout

4. FINDINGS AND DISCUSSIONS

Rainfall affects roundabout operations in a variety of ways. First, there is a reduction in friction between the road surface and tires of vehicles passing the roundabout during rainy conditions. Secondly, rainfall affects visibility and drivers' behavior. Visibility can be severely restricted during rainy weather. Notwithstanding obscured windscreen view experienced by drivers, splash, and spray from other vehicles create additional visibility problems and to some extent drivers' anxiety and sometimes anger. Also, rainfall causes drivers to slow down their speed and journeys are seldom cancelled or delayed. As shown below in figure 3 and 4, typical entry and circulating flow profiles demonstrate the movement of vehicles as uniform flow in figure 3 which indicates that the circulating traffic flow is continuous and steady whereas figure 4 shows irregular and fluctuating trend, which implies that entry flow is a function of circulating flow.

The method of analysis adopted is stepwise for clarity purpose.

Step 1
The collected rainfall intensity, i, was divided into light rainfall (LR) ($i < 2.5$mm/hr), moderate rainfall (MR) ($2.5 \leq i < 10$ mm/hr) and heavy rainfall (HR) ($10 \leq i < 50$ mm/hr).

Step 2
Entry and circulating traffic volumes collected were separated into peak and off-peak period. The off-peak volume was used to minimize the effects of peak travel as shown in Tables 1 and 2.

Step 3
The off-peak traffic data were divided into three vehicle categories: passenger cars, light vans, and HGVs/trucks/buses. Passenger car equivalent values were modified. The modified values were used to convert the off-peak traffic volume to traffic flow.

Step 4
Entry traffic flows were related to circulating flows by way of linear regression to establish model equations for entry capacities as illustrated with equation 8. All model equations for all sites have the correct signs. The model equations were tested for acceptability. The coefficient of determination, R^2 was more than 0.5 in all cases, meaning that the model equation can be used for prediction. Results of the t-test were higher than 2 at 95% level of confidence, meaning the variables used were significant, and the F test were greater than 4 in all cases suggesting that the model did not happen by chance.

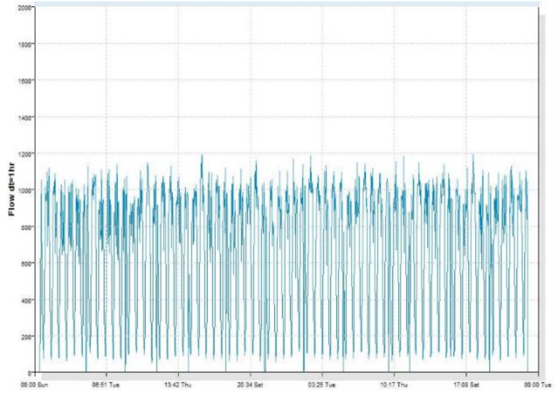

Figure 3: Typical circulating traffic flow

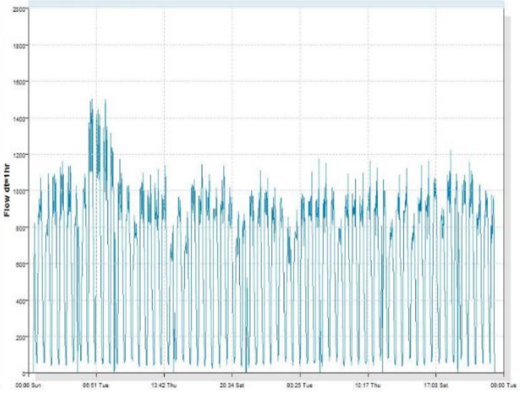

Figure. 4: Typical entry traffic flow

Table 1: Typical Entry Hourly Traffic flow (Off-Peak)

At-grade Roundabout
Two-lane entry approach; Approach half width: 6.5 meters; Entry width: 11.5

Period	Dry veh/h	Light Rain veh/h	Moderate Rain veh/h	Heavy Rain veh/h
1	499	1006	924	1052
2	1044	912	912	768
3	1006	1265	924	626
4	1018	1123	1020	789
5	1255	1325	1054	709
6	972	972	1128	792
7	972	982	1161	1063
8	926	912	1162	796
9	936	1017	972	811
10	794	1157	962	663
11	1017	1114	1017	787
12	948	1039	1032	818

Table 2: Typical Circulating Hourly Traffic flow (Off-Peak)

At-grade Roundabout

Two-lane circulating approach; Circulating stream width: 11 meters

Period	Dry veh/h	Light Rain veh/h	Moderate Rain veh/h	Heavy Rain veh/h
1	1459	1039	861	777
2	1063	1109	871	1094
3	1137	744	876	1317
4	1128	938	777	1130
5	905	670	765	1154
6	1164	1015	672	1041
7	1255	1113	624	778
8	1212	1094	643	1001
9	1341	998	850	1106
10	1334	864	744	1164
11	1123	984	818	999
12	1190	996	717	934

Step 5

Model equation 8 in figure 5, is used to estimate capacity. From equation 8, entry capacity when circulating flow is zero is about 2278pcu/h. In any case, to suggest that circulating flow is zero would depict that vehicles are entering the roundabout at the free flow rate. That's would be a rare occurrence at roundabouts. It may even be called an exaggeration of the observed traffic stream.

[8] $Qe = -1.1148Qc + 2278.4$ $R^2 = 0.83$

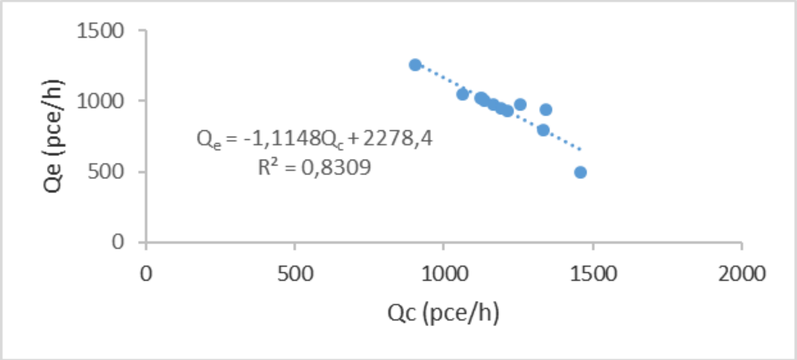

Figure 5: Entry flow (q_e) versus circulating flow (q_c) for dry weather condition

Step 6

The geometric design correction factor (k) was estimated where entry angle is 60^0 and entry radius is 60m.

$$k = 1.151 - 0.00347\varphi - 0.978/r = 0.92$$

Now, if the computed correction factor *k* is applied to equation 8, then

[9] $Q_e = 0.92(-1.1148Qc + 2278.4)$, $Q_e = 2096 - 1.03Qc$

Step 7

Once the entry capacity has been estimated, Equation 6 is then applied to estimate the delay (*d*) and Equation 7 used to estimate queue length (Q_{95}) as illustrated below.

$$d = \frac{3600}{\{2096-1.03Q_c\}} + 900T\left[\left(\frac{q_E}{Q_E}-1\right) + \sqrt{\left(\frac{q_E}{Q_E}-1\right)^2 + \frac{\left(\frac{3600}{\{2096-1.03Q_c\}}\right)\left(\frac{q_E}{Q_E}\right)}{450T}}\right] + 5$$

$$Q_{95} = 900T\left[\left(\frac{q_E}{Q_E}-1\right) + \sqrt{\left(\frac{q_E}{Q_E}-1\right)^2 + \frac{\left(\frac{3600}{(2096-1.03Q_c)}\right)\left(\frac{q_E}{Q_E}\right)}{150T}}\right]\frac{(2096-1.03Q_c)}{3600}$$

Where; $Q_E = 2096 - 1.03Q_C$

Dry weather, Q_E = 2096 pcu/hr; q_E = 1488 pcu/hr; T = 0.25; $\frac{q_E}{Q_E}$ = 0.71: delay = 5.80s/veh; queue length = 6.75 veh

Heavy rainfall, Q_E = 1493pcu/hr; q_E = 1063pcu/hr T = 0.25; $\frac{q_E}{Q_E}$ = 0.71: delay = 8.07s/veh; queue length =6.55veh

Delay from heavy rainfall = 8.07s – 5.80s = 2.15s.

Step 8

Results are tested for sensitivity to volume/capacity ratio using extreme and threshold values.

Assuming that volume capacity ratio is (v/c) = 0,

Dry weather, Q_E = 2096 pcu/hr; q_E = 0; T = 0.25; $\frac{q_E}{Q_E}$ = 0.00: delay = 6.72s/veh; queue length = 0.00 veh

Heavy rainfall, Q_E = 1493pcu/hr; q_E = 0 T = 0.25; $\frac{q_E}{Q_E}$ = 0.00: delay = 7.41s/veh; queue length = 0.00veh

The result is shown in table 3. The result shows that when there was no vehicle at the roundabout entry, entry delay still occur and the value for each site where almost of same, which implies that the delay was as a result of the geometry, the queue length show that there was no queue at the entry.

Table 3: Summary of geometric delay (sensitivity test based on $^{q_e}/_{Q_e}$ = 0.00)

	Site 01				Site 02				Site 03			
	Qe	$^{q_e}/_{Q_e}$	d(s)	L(veh)	Qe	$^{q_e}/_{Q_e}$	d(s)	L(veh)	Qe	$^{q_e}/_{Q_e}$	d(s)	L(veh)
Dry	1785	0.00	7.02	0.00	1104	0.00	8.26	0.00	2096	0.00	6.72	0.00
LR	1593	0.00	7.26	0.00	1188	0.00	8.03	0.00	1787	0.00	7.01	0.00
MR	1397	0.00	7.58	0.00	1056	0.00	8.41	0.00	1593	0.00	7.26	0.00
HR	1238	0.00	7.91	0.00	984	0.00	8.66	0.00	1493	0.00	7.41	0.00

Note: q_e-entry flow (pc/hr); Q- Entry Capacity (pc/hr); d-Delay (s/veh), L Queue length (veh)

Assuming that the volume capacity ratio is at the threshold of 0.85, the result is shown in Table 4

When entry volume/capacity ratio is notched up to threshold (0.85) level, delays at all sites increases with increases in rainfall intensity but is difficult to separate the effect of delay caused by rainfall from the effect caused by peak period because the reaction of drivers at peak period vary under different rainfall intensity.

Table 4: Summary of geometric delay (sensitivity test based on $^{q_e}/_{Q_e}$ = 0.85 threshold)

	Site 01				Site 02				Site 03			
	Qe	$^{q_e}/_{Q_e}$	d(s)	L(veh)	Qe	$^{q_e}/_{Q_e}$	d(s)	L(veh)	Qe	$^{q_e}/_{Q_e}$	d(s)	L(veh)
Dry	1785	0.85	16.98	12.40	1104	0.85	23.36	11.07	2096	0.85	15.35	12.82
LR	1593	0.85	18.27	12.10	1188	0.85	22.22	11.28	1787	0.85	16.96	12.41
MR	1397	0.85	19.92	11.74	1056	0.85	24.09	10.95	1593	0.85	18.27	12.10
HR	1238	0.85	21.61	11.40	984	0.85	25.29	10.74	1493	0.85	19.06	11.92

Note: q_e-entry flow (pc/hr); Q- Entry Capacity (pc/hr); d-Delay (s/veh), L Queue length (veh)

When the volume capacity ratio was assumed to operate at capacity i.e. volume capacity ratio of 1.00. The result is as shown in Table 5. The result indicated that the queue length increased from the average of 12 vehicles under the threshold volume capacity condition of 0.85 to above 20 vehicles in all the dry and rainfall weather conditions. The result shows that the increases in delay and queue were as a consequence of the roundabout operating at capacity and not due to rain effect.

According to HCM 2010 LOS criteria table for roundabouts, estimated delays for dry weather and heavy rain condition when volume/capacity ratio is one would be in class as F, bearing in mind that F is the worst class. The estimated delays when volume/capacity ratio is 0.85 would be in class E. It can be seen from the results shown in table 4 and 5 that effect off peak travel has made it difficult to separate effect from heavy rainfall.

Table 5: Summary of geometric delay (sensitivity test based on $^{q}{}_{e}/_{Qe}$ = 1.00)

	Site 01				Site 02				Site 03			
	Qe	$^{q}{}_{e}/_{Qe}$	d(s/veh)	L(veh)	Qe	$^{q}{}_{e}/_{Qe}$	d(s/veh)	L(veh)	Qe	$^{q}{}_{e}/_{Qe}$	d(s/veh)	L(veh)
Dry	1785	1.00	37.14	25.87	1104	1.00	46.57	20.35	2096	1.00	34.52	28.04
LR	1593	1.00	39.15	24.44	1188	1.00	44.96	21.11	1787	1.00	37.12	25.89
MR	1397	1.00	41.63	22.89	1056	1.00	47.58	19.90	1593	1.00	39.15	24.44
HR	1238	1.00	44.08	21.55	984	1.00	49.23	19.21	1493	1.00	40.35	23.66

Note: q_e-entry flow (pc/hr); Q- Entry Capacity (pc/hr); d-Delay (s/veh), L Queue length (veh)

Step 9

Compute delay and queue for all surveyed sites with relevant survey data. By inputting corrected entry capacity ratio into delay equation 5. Tables 6 and 7 give the summary of the entry vehicle performance at multilane roundabout under the dry weather and rainy conditions. The results indicate that entry vehicle performance was affected by rainfall in all the sites. Delay increases from 13.06 s/veh to 14.68 s/veh at site 01, from 10.48 s/veh to 12.07 s/veh at site 02 and from 5.8 s/veh to 8.07 s/veh at site 03. The discrepancy between delay findings at different sites may be attributed to a few factors. First, it is assumed that drivers behave the same way on approach to a roundabout in which vehicles move in a stop and go fashion. In reality, both circulating and entering motorists are conscious of the rainy conditions, often to the detriment of motorists entering the facility that must give way. This is so because the drivers entering the facility are not able to judge correctly acceptable gap in the circulating flow due to the rainy condition. They simply decelerate and then proceed cautiously into the circulating stream, sometimes forcing circulating flow to decelerate and give way. Second is the issues of rainfall intensity distribution. The rainfall intensity ranges in each class distribution may have contributed to some over lapses in entry flow classifications. This issue is very pronounced in heavy rainfall where the range is between 10mm/hr and 50mm/hr. It is difficult to place borderline rainfall conditions correctly; hence, sub-classes were created in the analysis to address this anomaly. Third is the issue of passenger car equivalent values modification. Since existing passenger car equivalent values were estimated under dry weather condition, they were modified to reflect prevailing rainy condition. Notwithstanding the issues raised, it can be asserted that delays at roundabout can be triggered by rainfall. The queue length in each site are almost the same but the delay for each vehicle are different this show that rainfall has effect on the delay experienced by the vehicle at the roundabout due to rainfall.

Table 6: Summary of control delay findings

	Site 01				Site 02				Site 03			
	Q_e	$^{q}{}_{e}/_{Qe}$	d(s/veh)	L(veh)	Qe	$^{q}{}_{e}/_{Qe}$	d(s/veh)	L(veh)	Q_e	$^{q}{}_{e}/_{Qe}$	d(s/veh)	L(veh)
Dry	1785	0.76	13.06	8.23	1104	0.70	10.48	6.10	2096	0.71	5.80	6.75
LR	1593	0.76	14.00	8.12	1188	0.72	10.39	6.65	1787	0.74	7.49	7.56
MR	1397	0.74	14.50	7.35	1056	0.73	12.02	6.81	1593	0.72	7.83	6.87
HR	1238	0.71	14.68	6.42	984	0.71	12.07	6.25	1493	0.71	8.07	6.55

Note: q_e-entry flow (pc/hr); Q- Entry Capacity (pc/hr); d-Delay (s/veh), L Queue length (veh)

Table 7: Delay and Queue from Rainfall

	Site 01			Site 02			Site 03		
	d(s/veh)	Δd	L(veh)	d(s/veh)	Δd	L(veh)	d(s/veh)	Δd	L(veh)
Dry	13.06	0.00	8.23	10.48	0.00	6.10	5.80	0.00	6.75
LR	14.00	0.94	8.12	10.39	0.09	6.65	7.49	1.47	7.56
MR	14.50	1.44	7.35	12.02	1.54	6.81	7.83	1.56	6.87
HR	14.68	1.62	6.42	12.07	1.59	6.25	8.07	2.15	6.55

Note: d-Delay (s/veh), L Queue length (veh), Δd delay from rainfall.

4. CONCLUSIONS

The rainfall impact study reported in this paper was carried out in Durban, South Africa. The purpose of the study is to investigate whether rainfalls have effects on entry delays and queues at the multilane roundabout. Entering and circulating traffic flows at three locations were collected during dry weather and rainy conditions, analysed and their outcomes compared. Based on the synthesis of evidence obtained from the relationship between roundabout entry delay and rainfall intensity, it is correct to conclude that rainfall has effect on entry delays and increases the delay per queue vehicle at roundabouts. The effects of light and moderate rainfalls on delays and queues are not so severe. In addition, it is affirmed that roundabout capacity estimation based on the linear regression technique is more relevant to empirical studies than estimation based on theoretical models. However, a fusion of theoretical and empirical methods is likely to be more robust when estimating delays and queues than the singular approach. It is concluded that rainfall has effect on delay and queue at multilane roundabout irrespective of rainfall intensity. However, care should be taken when conducting roundabout entry delay under rain condition because there is a distinction between delay during rainfall and delay attributable to rainfall conditions. The paper focused on delays and queues during rain.

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