Capacity and Performance Analysis of 3 Roundabouts in Sunyani

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Abstract: ***Nowadays traffic congestion at intersections is one of the main societal, economic and environmental problems in urban areas which particularly become severe during peak hours. Roundabouts are being weigh up as substitute for traffic control device capable of improving safety and effective functioning at nodes. This study analyzed capacity and performance of 3 major roundabouts (Jubilee Park, Cocoa House and Post Office) in Sunyani, Ghana. Traffic data were collected manually at the roundabouts during peak hours in the interval of 15 minutes. Also, as-built geometric data of the roundabouts were measured in the field. Synchro plus SimTraffic 7 software's were used to run computer simulations to estimate the capacities and performances of the roundabouts. Results showed that the Jubilee Park and Post Office roundabouts were performing above capacities based on the overall volume to capacity ratios of 0.78 and 1.13 respectively, with intersection capacity utilization (ICU) level of service H. The roundabouts were at least 9% above capacity and were being subjected to congestion periods in excess of 120 minutes per day. Similarly, the Cocoa House roundabout with volume to capacity ratio of 0.51 and ICU level of service G was 9% above the traffic-carrying ability and undergoing successive congestion periods of 60 to 120 minutes. The 3 roundabouts should be signalized to improve on vehicular movement.***

Keywords: Capacity and performance analysis, intersection capacity utilization, Jubilee Park roundabout, Cocoa House roundabout, Post Office roundabout

1. Introduction

Travel time savings that result from increased highway capacity help individuals to apportion added time to their activities and even upsurge their number, relatively than time spend traversing [1]. At a minimum, they should be no worse off. On the other hand, this additional travel time may have negative environmental drawbacks and externalities that commuters do not frequently anticipate in their travel arrangements [2]-[3]. Likewise, conflicting traffic at most road junctions results in time losses as vehicles compete for time and space [1]-[4]-[5].

Traffic engineers and road users have writhed to regulate conflicting traffic at wide-ranging of highway nodes since the advent of automobiles [6]-[7]. In the 1960's traffic circles were introduced in the US and Europe as means to control conflicting traffic at various intersections [8]-[9]-[10]-[11]-[12]. Their popularity dropped significantly owing to the growth in traffic volumes that led to considerable increase in delay at rotary intersections in the 1950's [13]-[14]. Conversely, roundabouts usage became increasingly popular substitute to traffic signals for junction control globally during the 1980's due to improvements made in their design [9]-[6].

Contingent on the operational situations, there are copious merits that roundabouts have compared to traffic signals [15]. Roundabouts provide better safety than other schemes of traffic controls [10]. Among the various forms of speed calming measures, roundabout installations in general have shown to be the most effective. Usually, at roundabouts, the impact angle is lesser and in the event of crashes the severity is at all times less [18]. They reduce crash severity as head-on as well as right-angle conflicts are almost removed and can handle higher volume of traffic with less delay compared to signalized control intersections [19]. They probably use less area of land as turn pocket lanes are not required. Furthermore, they provide superior energy and maintenance costs compared to other intersection treatments [19]-[20]-[21]-[22]. Nonetheless, their successful design and implementation depend largely on communication and quality engineering. They are as well influenced by public opinions and driver education [21]-[22]-[12]-[23].

Due to the increasing population and economic growth in the Sunyani municipal, traffic volumes continue to grow especially at roundabouts while the available lanes remain relatively fixed. This has led to many commuters spending hours stuck in traffic everyday thereby prolonging their travel times, increasing their fuel consumptions and polluting the environment specifically, Jubilee Park, Cocoa House and Post Office roundabouts. As roundabouts continue to be recommended as an intersection alternative for safety and capacity reasons, engineers need to have confidence that they are analyzing roundabouts appropriately [5]-[2]. Inaccurate capacity evaluations could lead to undesirable penalties of increased unsafety or increased delay and queuing [26]. Also, bad road planning and inferior geometric conditions of roundabouts may cause substantial impact on their operational capacity and traffic congestion [19]-[27].As traffic volumes continue to surge, this study provides insight into how to make the best use of these roundabouts as one of the diverse solutions to address the congestion challenge. The study also addressed the central issue of how to accommodate these traffic volumes without sacrificing the integrity of the roundabout.

This paper is aimed at evaluating the operational capacities and performances of 3 roundabouts in Sunyani and to find effective ways of resolving the peak periods traffic congestion challenges. The study estimated the capacity and level of service (LOS) at the roundabout and evaluated the performance of the roundabouts during peak periods using computer simulations. Not only would this study help planners and local road agencies develop countermeasures to reduce time spent in traffic but also fuel consumption and pollution.

Because traffic congestion at the roundabouts is characterized by creep or snail speeds, longer trip times and increased vehicular queuing which mostly lead to drivers frustrations.

2. Capacity of Roundabouts

The two principal methods of evaluating the operational performance of roundabouts are: gap acceptance method and empirical regression technique [28]-[29]. Gap acceptance method is founded on the principle that an individual driver, at a signalized intersection, will wait for a suitable gap in the free flow traffic stream before they enter or cross it [30]-[31]. For roundabout in particular, the driver making the entry maneuvers must give in to turning traffic before entering into it [32]. Any driver wanting to enter the roundabout must scan the traffic to his left and wait for an adequate gap in the circulating traffic before entering the roundabout when approaching the yield line [33].The second method is founded on the principle that the geometric features (approach half width, v; entry width, e; entry radius, r and inscribed circle diameter, D) of any roundabout significantly affect its working performance [41]. In addition to the geometric features, there are three other design elements which are key to analyzing capacity by the latter method:

1. Average effective flare length (l') – it is the average length of flare on the approach that can be used by vehicles entering the roundabout.
2. Sharpness of flare (S) – measures the rate whereupon added width is established within the entry flare.
3. Entry angle(∅)- it is the optimum conflicting angle flanked by entering and circulating traffic streams.

2.1 Capacity of Entry Lane

There is strong correlation between the entering flows and the seven geometric parameters (continuous variables) listed above for roundabouts capacity [19]. The most sensitive parameter of all is the entry width, which like all other variables is a continuous variable. Using the roundabouts capacity model (equation 1), developed by Kimber with the Transportation Research Laboratory [41] in mid 1970s, the capacities of each entry lanes were estimated.

$$Q_e = \begin{cases} k(F - f_c Q_c) & if\ f_c Q_c \le F \\ 0 & if\ f_c Q_c > F \end{cases} \quad (1)$$

Where,

Q_e = Entry capacity into the circulatoryarea in passenger car units per hour (PCU/hr.).

Q_c = Circulating flow in conflict with entry flow in PCU/hr

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

$F = 30x_2$.

$f_c = 0.210 t_D(1 + 0.2x_2)$

$t_D = 1 + \frac{0.5}{1 + \exp\left(\frac{D-60}{10}\right)}$

$x_2 = v + \frac{e-v}{1+2S}$

$S = \frac{1.6(e-v)}{l'}$

e = Entry width, m,

v = Approach half width, m,

l'= Effective flare length, m,

S = Sharpness of flare, m/m,

D = Inscribed circle diameter (ICD), m,

∅ = Entry angle, °

r = Entry radius, m.

2.2 Level of Service Thresholds

Table 1 provides a summary of the various intersection capacity utilization (ICU) LOS, their corresponding ICU percentages, and descriptions of the associated congestion thresholds.

Table1: Roundabout ICU LOS thresholds used

LOS	*ICU (%)*	*Description of threshold Intersection*
A	≤ 55	No congestion.
B	55<ICU<64	Very minimal congestion.
C	64<ICU<73	Minimal congestion.
D	73<ICU<82	Gradually moving toward congestion situations.
E	82<ICU<91	On the edge of congested situations.
F	91<ICU<100	Above the traffic-carrying ability and probably undergoes congestion periods of 15 to 60 successive minutes.
G	1005<ICU<109	In excess of 9% of the traffic-carrying ability and undergoes congestion periods of 60 to 120 successive minutes.
H	>109%	At least 9% above the traffic-carrying ability and experiences congestion periods of over 120 minutes per day.

(Source: [34])

The ICU approach estimates what percentage of intersection traffic capacity is being served. Percentages below 100% indicate reserve intersection capacity and percentages over 100% indicate traffic volumes are above intersection capacity. An intersection with an ICU LOS E or higher can have a phasing plan that provides LOS E or improved with the highway capacity manual (HCM) method. Per an ICU LOS F, the node will be above capacity for at least 15 minutes during the peak period. Conversely, it may be likely to get an adequate HCM LOS when the intersection is above capacity by a phasing plan supporting the highest volume movements [35]-[36].

2.3 Roundabout Traffic Flow Simulations

Synchro is a software use for optimizing traffic signal phasing and executing capacity analysis [37]. The software optimizes splits, offsets, and cycle lengths for individual intersections, an arterial, or a complete network. It does largely micro simulation and animation of vehicular traffic. With Synchro, individual vehicles are modelled and displayed traversing a street network. Synchro furthermore models signalized and unsignalized intersections, freeway sections and roundabouts.

2.4 Synchro Algorithm

Simulation is fundamentally a dynamic depiction of some part of the physical world accomplished by constructing a computer model and imitating the system over time[37]. The outcomes from every simulation model will practically reflect the model if it imitates the exact real world features of concern to the one doing the analysis. Three important algorithms are available for defining vehicle movement through a network if it is given performance and driver features.

1) Car following

These models explain how one vehicle follows another vehicle in continuous flow. The mathematical models control behavior and distribute vehicles in traffic stream. Synchro alters headway with driver type, speed and geometry of highways while SimTraffic creates subordinate saturation flow rates [37].

2) Lane changing

Among the three algorithms, lane changing has proved to be the unpredictable characteristics of simulation models. The three main categories of lane-changing are; mandatory lane changes, discretionary lane changes and positioning lane changes. The latter lane changing technique is applied any time there is heavy queuing which is usual difficult for modelling positioning lane changes. Vehicles often passed back of queue in advance trying lane change and their exactness depends on the level of saturation and quantity of entering or leaving points.

3) Gap acceptance

Analytical models compute capacity using gap-acceptance relations that do not involve observations under congested circumstances. If default values are excessively aggressive, vehicle delay will be undervalued which at times have severe implication for frontal roads. Contrariwise, values which are too conservative may demonstrate the need for a traffic installation signal when one is not actually needed [36]. This technique is properly used in network-wide SimTraffic simulations [39].

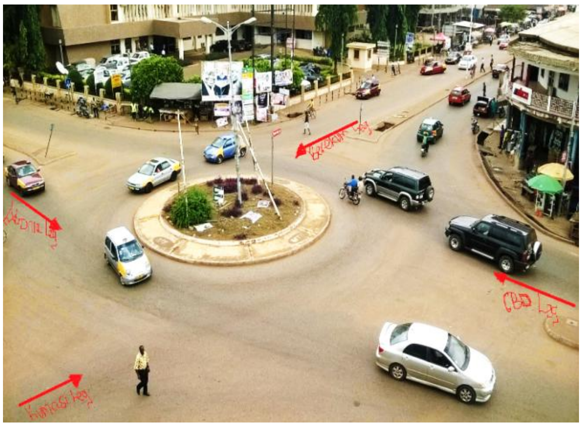
3. Methodology

3.1 Description of the Area of Study

Sunyani municipality is the regional capital of the BrongAhafo Region of Ghana and is among the fastest growing cities in Ghana. The region shares borders with Wenchi municipal to the north, Berekum municipal and Dormaa East district to the west, Asutifi district to the south and Tano South district to the east. According to the 2012 housing and population census, Sunyani municipal has population of about 248, 496 [40].

The roundabouts used for this study were; Post Office (Node 1), Cocoa House (Node 2) and Jubilee Park (Node 3). The aerial views of the last two are shown in Figures 1(a) and 1(b).

(a)



(b)

Figure 1: Aerial views of the (a) Post Office and (b) Cocoa House roundabouts in Sunyani

The multilane roundabouts with similar characteristics have 2 entry lanes from each approach and 2 circulating lanes with non-traversable median. The inner circles which allows circulation to other lanes in all directions have track aprons on top with grasses planted in them. The roundabouts have pedestrian crosswalks on each approach for safe pedestrians crossing. The 4-legged roundabouts have traffic lights at their centers.

The Post Office roundabout allows traffic flow from Berekum road, Sunyani Township road, Municipal Hospital road and Baakoneaba road.

The Leg 1 of the Cocoa House roundabout is arterial road from the Kumasi, leg 2 is road from the central business district (CBD), leg 3 is the arterial road from Berekum and leg 4 is the road from Atronie.

The Jubilee Park roundabout intersection has 4 principal arterials, namely Kumasi road, Sunyani Township road, Nana Bosomah Market road and the GETFund Hostel road.

3.2 Data collection

1) Turning Movement Counts

Traffic data was manually collected at all the 3 roundabouts. Turning movement counts were done between 07:00hours-10:00hours during the AM peak period and 14:00hours-18:00hours during the PM peak period of the day at the roundabouts. Two enumerators each were put at locations A, B, C and D on the 4 approaches to the roundabouts as shown in Figure 2. Vehicles entering and leaving each road were counted using the vehicle number plate method. All the Turning movement counts for left-turn (LT), through (TH) and right-turn (RT) were conducted at 15 minutes intervals using count sheet forms.

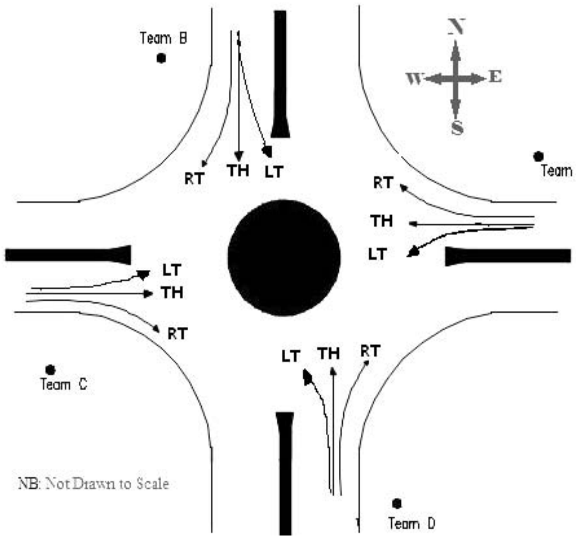


Figure 2: Enumerator positions and turning movements during traffic data collection

3.3 Geometric Data

Since Equation 1 is empirically derived, it can clearly be shown that due to the offside priority rule, entry capacity, Q_A reduces as the rotating flow Q_c upsurges. Using 4-legged roundabout as the case for this study Q_c was the sum of the entry flows from the preceding legs which have not already exited the roundabout before passing the leg whose entry capacity is being calculated. The entry width, e in the equation was measured from the point designated as A along the normal to the nearside curb. The approach half-width, v was measured along a normal from a point in the approach upstream from any entry flare from the median line, or from the offside edge of the dual carriageways to the nearside curb. The diameter, D denotes the size of the largest circle that can be inscribed inside the node peripheral which was measured from the center of the roundabout to the yield lines on the four approaches and mean results multiplied by 2. The average effective flare length 1 was measured along the curved line CHin parallel to line JK and at a distance (e- v)/2 from it. The entry radius r was measured as the minimum radius of curvature of the nearest curb line at the entry.

3.4 Data Analysis

The Kirnber's method for calculating the capacity of a roundabout which is founded on the principle that the geometric elements of a roundabout significantly affect its operational level of performance was used to analyze the data. The gap acceptance method is based on driver behavior information and therefore do not fit the kind of the data collected [35]. The capacity and delay formula developed by Kimber and others were based on much larger sample sizes ranging between 16-35 sites [41]. These collections of sites were unlikely for this study and may not be possible due to the small number of roundabouts in the Sunyani municipality. Due to this, evaluating the capacities and performances with only 3 sites might have over or under estimated the real effect of the geometric characteristics on the working performance of the roundabout. Nonetheless, the researcher believes results were not severely affected since excellent precautionary measures were taken during data collection stage to keep the likely errors minimal. Microsoft Excel 2013 version was used to estimate the entry capacity into the circulatory area. The traffic flows at the roundabouts were simulated in Synchro plus SimTraffic software's.

4. Results and Discussion

4.1 Geometric elements

Geometry measurements for each roundabout were obtained from as-built construction plans. The measured geometric elements of the roundabouts are shown in Table 2. The entry widths ranged between 8.6 and 8.8m and that of the approach half-widths from 7.5 to 7.7m. The ICDs and average effective flare lengths ranged from 38 to 40m and 4 to 7mrespectively. The circulating widths ranged between 14 to 15m with internal diameters of 14 to 16m. The entry radii were each 60m.

4.2 Analysis of turning movement counts

1) Traffic composition

The vehicle compositions of the roundabouts are shown in Table 3. From Table 3, small vehicles made up the largest category with an average composition of 90%. Medium vehicles had average composition of 7% while the remaining percent comprise large vehicles. Post Office roundabout recorded the largest number of vehicles count per hour of 2293vph whilst Cocoa House had the lowest vehicles count per hour of 1783vph.

Table 2: Geometric elements of the roundabouts

Parameter Geometric/Design	Symbol	Unit	Measure			Practical limits
			Post Office	Cocoa House	Jubilee Park	
Entry width	e	m	8.6	8.7	8.8	4 – 15
Approach half width	v	m	7.7	7.5	7.7	2 – 7.3
Entry radius	R	m	60	60	60	6 – 100
Inscribed circle diameter (ICD)	D	m	38	40	40	15 – 100
Average effective flare length	l'	m	4	7	6.5	1 – 100
Circulating Width	w	m	15	16	14	-
Internal Diameter	d	m	14	14	16	-

Table 3: Vehicle composition at the roundabouts

Vehicle Category	*Vehicle Composition in vph and %*		
	Post Office	*Cocoa House*	*Jubilee Park*
Small Vehicles	2113 (92%)	1570 (88%)	1646 (90%)
Medium Vehicles	124 (5%)	167 (9%)	147 (8%)
Large Vehicles	56 (3%)	46 (3%)	29 (2%)
Total	2293 (100%)	1783 (100%)	1822 (100%)

2) Turning volumes

The total turning approach volumes (V) at the roundabouts are shown in Table 4. The North Bound Through (NBT), V_2 had the maximum hourly flow rate of 284vph at the Post Office roundabout. It implied that 284 vehicles routed the NBT direction in an hour. In the same way, North Bound Right (NBR), V_3 had the minimum hourly flow rate of 133vph, indicating that 133 vehicles travelled the NBR direction in an hour.

Also, at the Jubilee Park roundabout, the maximum hourly flow rate was 733vph and the movement was in the South Bound Through (SBT), V_8 direction. Also indicating that, 733 vehicles moved in the SBT direction within an hour. The minimum hourly flow rate was 19vph and the movement was in the West Bound Left (WBL), V_{10}. This meant that 19 vehicles travelled in the WBL direction in an hour.

North Bound Right (NBR), V_3 had the highest hourly flow rate of 222vph at Cocoa House roundabout. This meant that 222 vehicles travelled in the North Bound Right (NBR) direction in an hour. Similarly, North Bound Left (NBL), V_1 had the lowest hourly flow rate of 58vph, meaning 58vehicles passed through the North Bound Left direction within an hour.

3) Approach volumes

The summary of the approach volumes of the 3 roundabouts are shown in Table 5. At Node 1, Berekum approach (Q_A, N) had the highest approach flow of 684vph. The Baakoneaba approach (Q_A, E) volume was 673vph. The lowest approach volume was the Municipal Hospital (Q_A, W) approach of 551vph.

The Atronie approach (Q_A, E) recorded the maximum approach flow of 564vph at the Cocoa House roundabout. The Kumasi approach (Q_A, S) volume was 492vph. The minimum approach volume of 444vph came from the CBD (Q_A, W) leg. Correspondingly, the Berekum approach from the North (Q_A, N) had a total approach volume of 532vph.

Similarly, Kumasi approach had the highest approach flow of 848vph at Jubilee Park Roundabout. The Kumasi approach from the South (Q_A, S) recorded a total approach volume of 642vph. From Sunyani Township road, 796vph moved to other approaches while 544vph moved from Nana Bosomah Market road to other approaches. GETFund Hostel approach gave the lowest approach volume of 148vph.

4) Circulating flows

The circulating flows of the roundabouts are respectively shown in Table 6.

At the Post Office roundabout (Node 1), Berekum approach, had the maximum circulating flow of 688vph with factored flow of 851pcu/hr. The minimum was the Kumasi approach with circulating flow of 634vph and factored flow of 713pcu/hr. Likewise, the Baakoneaba approach recorded circulating flow of 744vph. In terms of pcu, this was 837pcu/hr. Municipal Hospital approach had circulating flow of 610vph with factored flow of 755pcu/hr.

At Node 2, the CBD approach had the highest circulating flow of 624vph with factored flow of 772pcu/hr. The lowest was the Berekum approach with circulating flow of 297vph and factored flow of 368pcu/hr. The Atronie approach had circulating flow of 525vph however, in terms of pcu, this translated into 650pcu/hr. Kumasi approach had circulating flow of 587vph with factored flow of 726pcu/hr.

The Nana Bosomah Market approach had the highest circulating flow of 823vph which in terms of factored flow is 1018pcu/hr. at Node 3. This is followed by GETFund Hostel approach recording circulating flow of 800vph and in pcu terms of 990pcu/hr. The Kumasi approach had the lowest circulating flow of 155vph, with factored flow of 192pcu/hr. Also, the Sunyani Township approach had circulating flow of 558vph with factored flow of 690pcu/hr.

Table 4: Turning volumes

Approaches	Roundabout Hourly Flow Rate (vph)		
	Post Office	Cocoa House	Jubilee Park
North Bound Left (NBL), V_1	267	58	44
North Bound Through (NBT), V_2	284	213	590
North Bound Right (NBR), V_3	133	222	213
East Bound Left (EBL), V_4	221	205	30
East Bound Through (EBT), V_5	255	151	486
East Bound Right (EBR), V_6	166	88	27
South Bound Left (SBL), V_7	218	213	26
South Bound Through (SBT), V_8	263	164	733
South Bound Right (SBR), V_9	192	156	36
West Bound Left (WBL), V_{10}	193	189	19
West Bound Through (WBT), V_{11}	189	156	99
West Bound Right (WBR), V_{12}	169	218	30

Table 5: Approach volumes

Approach ID	*Approach Name*	*Approach Flow (vph)*	*Roundabout Approach Volume (Q_A) (vph)*		
			Post Office	*Cocoa House*	*Jubilee Park*
SB	South	$V_4 + V_5 + V_6$	642	492	848
EB	East	$V_{10} + V_{11} + V_{12}$	551	444	544
NB	North	$V_1 + V_2 + V_3$	684	532	796
WB	West	$V_7 + V_8 + V_9$	673	564	148

Table 6: Circulating flow at roundabouts

Approach	*Node*	*Flow in Circulation*	*Flow, Qc (vph)*	*Flow in pcu/hr (x1.1)*	*Factored Flow (x1.125)*
Kumasi	1	$V_{11} + V_{12} + V_7$	576	634	713
Municipal Hosp.		$V_2 + V_3 + V_{10}$	610	671	755
Berekum		$V_1 + V_5 + V_6$	688	757	851
Baakoneaba		$V_4 + V_8 + V_9$	676	744	837
Kumasi	2	$V_{11} + V_{12} + V_7$	587	646	726
CBD		$V_2 + V_3 + V_{10}$	624	686	772
Berekum		$V_1 + V_5 + V_6$	297	327	368
Atronie		$V_4 + V_8 + V_9$	525	578	650
Kumasi	3	$V_{11} + V_{12} + V_7$	155	171	192
BosomahMkt		$V_2 + V_3 + V_{10}$	823	905	1018
Sunyani Township		$V_1 + V_5 + V_6$	558	614	690
GETFund		$V_4 + V_8 + V_9$	800	880	990

5) Entry capacities, circulating flows & reserve capacities

The estimated entry capacities, circulating flows and reserve capacities for each approach at the roundabouts are presented in Table 7. At Node 1, Kumasi approach had the maximum entry capacity of 1713pcu/hr, while a minimum entry flow of 1612pcu/hr was recorded on the Berekum approach. Thus, 851 of the flow in the circulating zone from the North approach conflicted with the entry flow of 1612pcu/hr. While, 755 of the flow in the circulating zone from the West approach was in conflict with 1682pcu/hr. Equally from the South approach, 713 of the flow in the area of circulation conflicted with 1713pcu/hr. at the roundabout. Finally, 837 of the flow in the circulating zone conflicted with 1622pcu/hr from the East approach.

Berekum approach had the maximum entry capacity of 2054pcu/hr while CBD approach recorded the minimum entry flow of 1753pcu/hr at Node 2. Indicating that 726 of the flow in the circulating zone from the South approach conflicted with the entry flow of 1786pcu/hr whereas, 772 of the flow in the circulating zone from the West approach was in conflict with 1753pcu/hr. Congruently, 367 of the flow in the circulating zone from the North approach was in conflict with 2053pcu/hr. Also, 650 of the flow in the circulating zone conflicted with 1844pcu/hr from the East approach.

Highest circulating flow of 1018pcu/hr was recorded at the Nana Bosomah Market approach (Node 3). Signifying that 1018 of the flow in the circulating zone conflicted with the entry flow of 1600pcu/hr Kumasi approach had the lowest circulating flow of 192pcu/hr which conflicted with the entry flow of 2222pcu/hr. Similarly, Sunyani Township approach circulating flow of 690 was in conflict with 1847pcu/hr in the circulating area. Exactly 990 of the flow in the circulating zone conflicted with 1621pcu/hr at the GETFund Hostel approach.

6) Flow to capacity ratios

The flow to capacity ratios at the 3 roundabouts are presented in Table 8. Overall, the roundabouts are currently operating at full capacity. The maximum volume to capacity ratios for the roundabouts were;0.78 for the Post Office roundabout, 0.51 for the Cocoa House roundabout and 1.13 for the Jubilee Park roundabout.

7) Intersection capacity analysis

The performances of the 3 roundabouts after the capacity modelling against the ICU method are shown in Table 9.From Table 9, the Post Office and Jubilee Park roundabouts were performing above their capacities. This meant that the roundabouts were at least 9% above capacity and were undergoing congestion more than 2 hours per day. The Cocoa House roundabout was 9% beyond the traffic-carrying ability and experienced congestion periods of 60 to 120 successive minutes.

Table 7: Entry capacities, circulating flows and reserve capacities

Parameter	*Post Office*				*Cocoa House*				*Jubilee Park*			
	Kumasi	*Municipal Hospital*	*Berekum*	*Baakoneaba*	*Kumasi*	*CBD*	*Berekum*	*Atronie*	*Kumasi*	*Bosomah Market*	*Sunyani Township*	*GETFund Hostel*
e	8.6	8.6	8.6	8.6	8.7	8.7	8.7	8.7	8.8	8.8	8.8	8.8
v	7.7	7.7	7.7	7.7	7.5	7.5	7.5	7.5	7.7	7.7	7.7	7.7
l’	4	4	4	4	7	7	7	7	6.5	6.5	6.5	6.5
S	0.360000	0.360000	0.360000	0.360000	0.274286	0.274286	0.274286	0.274286	0.270769	0.270769	0.270769	0.270769
ICD	38	38	38	38	40	40	40	40	40	40	40	40
ø	60	60	60	60	60	60	60	60	60	60	60	60
r	60	60	60	60	60	60	60	60	60	60	60	60
M	6.049648	6.049648	6.049648	6.049648	6.049648	6.049648	6.049648	6.049648	6.049648	6.049648	6.049648	6.049648
X_2	8.223256	8.223256	8.223256	8.223256	8.274908	8.274908	8.274908	8.274908	8.413573	8.413573	8.413573	8.413573
t_D	1.450125	1.450125	1.450125	1.450125	1.440399	1.440399	1.440399	1.440399	1.440399	1.440399	1.440399	1.440399
f_c	0.805366	0.805366	0.805366	0.805366	0.803089	0.803089	0.803089	0.803089	0.811477	0.811477	0.811477	0.811477
F	2491.647	2491.647	2491.647	2491.647	2507.297	2507.297	2507.297	2507.297	2549.313	2549.313	2549.313	2549.313
K	0.928500	0.928500	0.928500	0.928500	0.928500	0.928500	0.928500	0.928500	0.928500	0.928500	0.928500	0.928500
Qc	713	755	862	838	726	772	367	650	192	1018	690	990
Qe	1780	1749	1669	1687	1786	1753	2054	1844	2222	1600	1847	1621

4.3 Synchro plus SimTraffic 7 simulations

The results of Synchro plus SimTraffic 7 simulations and animations of the 3 roundabouts in 3-D (three-dimensional) are shown in Figures 3 to 5. The lanes and geometrics, volumes and timings of the roundabouts are also shown in Tables 10 to14.

Table 8: Flow to capacity ratios at the 3 roundabouts

Approach	*Node*	*Flow in Circulation (Q_C) (vph)*	*Entry Capacity (pcu/hr.)*	*Entry Flow (Q_A) (pcu/hr.)*	*Reserve Capacity (%)*	*Flow to Capacity Ratio*
Kumasi	1	713	1713	846	51	0.49
Municipal Hosp.		755	1682	795	53	0.47
Berekum		851	1612	832	48	0.52
Baakoneaba		837	1622	683	58	0.42
Kumasi	2	726	1786	609	66	0.34
CBD		772	1753	549	69	0.31
Berekum		367	2054	658	68	0.32
Atronie		650	1844	698	62	0.38
Kumasi	3	192	2222	1049	53	0.47
Bosomah Market		1018	1600	673	58	0.42
Sunyani Township		690	1847	985	47	0.53
GETFund Hostel		990	1621	183	89	0.11

Table 9: Performances of roundabouts

Name of Node	*Type of Control*	*Maximum Volume to Capacity Ratio*	*ICU Proportion*	*ICU Level of Service*
Post Office	roundabout	0.78	128.7	H
Cocoa House	roundabout	0.51	100.0	G
Jubilee Park	roundabout	1.13	113.1	H

Figure 3: Simulated and animated (3-D) Post Office roundabout

Figure 5: Simulated and animated (3-D) Jubilee Park roundabout

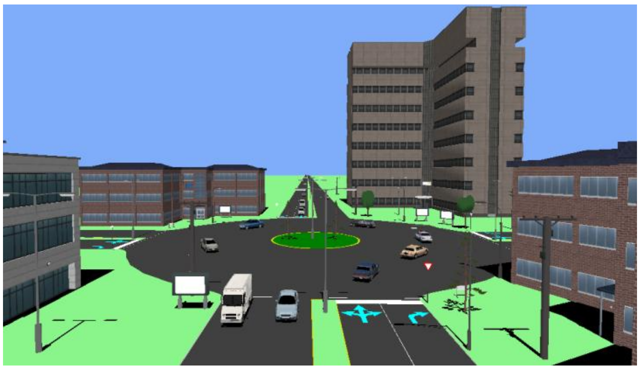


Figure 4: Simulated and animated (3-D) Cocoa House roundabout

Table 10: Lanes and geometrics of the Post Office roundabout

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Lane Width (m)	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Grade (%)		1%			1%			1%			1%	
Storage Length (m)	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0
Storage Lanes	0		1	0		1	0		1	0		1
Taper Length (m)	2.5		2.5	2.5		2.5	2.5		2.5	2.5		2.5
Lane Util. Factor	1.00	0.95	0.95	1.00	0.95	0.95	1.00	0.95	0.95	1.00	0.95	0.95
Ped Bike Factor												
Frt		0.995	0.850		0.994	0.850		0.997	0.850		0.994	0.850
Flt Protected		0.978			0.976			0.977			0.979	
Satd. Flow (prot)	0	1694	1480	0	1689	1480	0	1696	1480	0	1694	1466
Flt Permitted		0.978			0.976			0.977			0.979	
Satd. Flow (perm)	0	1694	1480	0	1689	1480	0	1696	1480	0	1694	1466
Link Speed (k/h)		48			48			48			48	
Link Distance (m)		1717.0			1859.1			1622.0			1128.4	
Travel Time (s)		128.8			139.4			121.7			84.6	
Intersection Summary												
Area Type:	Other											
Description: Post Office Roundabout												

Table 11: Lanes, volumes and timings of the Post Office roundabout

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Lane Width (m)	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Grade (%)		0%			0%			0%			0%	
Storage Length (m)	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0
Storage Lanes	0		1	0		1	0		1	0		1
Taper Length (m)	2.5		2.5	2.5		2.5	2.5		2.5	2.5		2.5
Lane Util. Factor	1.00	0.95	0.95	1.00	0.95	0.95	1.00	0.95	0.95	1.00	0.95	0.95
Ped Bike Factor												
Frt		0.996	0.850		0.991	0.850		0.989	0.850		0.994	0.850
Flt Protected		0.973			0.975			0.990			0.974	
Satd. Flow (prot)	0	1679	1473	0	1674	1473	0	1697	1473	0	1678	1473
Flt Permitted		0.973			0.975			0.990			0.974	
Satd. Flow (perm)	0	1679	1473	0	1674	1473	0	1697	1473	0	1678	1473
Link Speed (k/h)		48			48			48			48	
Link Distance (m)		1717.0			1859.1			1622.0			1128.4	
Travel Time (s)		128.8			139.4			121.7			84.6	
Intersection Summary												
Area Type:	Other											
Description: Jubilee Park Roundabout												

Table 12: Lanes, volumes and timings of the Cocoa House roundabout

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	221	255	166	193	189	169	267	284	133	218	264	192
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Lane Width (m)	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Grade (%)		1%			1%			1%			1%	
Lane Util. Factor	1.00	0.95	0.95	1.00	0.95	0.95	1.00	0.95	0.95	1.00	0.95	0.95
Frt		0.995	0.850		0.994	0.850		0.997	0.850		0.994	0.850
Flt Protected		0.978			0.976			0.977			0.979	
Satd. Flow (prot)	0	1694	1480	0	1689	1480	0	1696	1480	0	1694	1466
Flt Permitted		0.978			0.976			0.977			0.979	
Satd. Flow (perm)	0	1694	1480	0	1689	1480	0	1696	1480	0	1694	1466
Link Speed (k/h)		48			48			48			48	
Link Distance (m)		1717.0			1859.1			1622.0			1128.4	
Travel Time (s)		128.8			139.4			121.7			84.6	
Peak Hour Factor	0.90	0.90	0.90	0.80	0.80	0.80	0.93	0.93	0.93	0.95	0.95	0.95
Heavy Vehicles (%)	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	3%
Adj. Flow (vph)	246	283	184	241	236	211	287	305	143	229	278	202
Shared Lane Traffic (%)			10%			10%			10%			10%
Lane Group Flow (vph)	0	547	166	0	498	190	0	606	129	0	527	182
Enter Blocked Intersection	No	No	No	No	No	No	No	No	No	No	No	No
Lane Alignment	Left	Left	Right	Left	Left	Right	Left	Left	Right	Left	Left	Right
Median Width(m)		2.0			2.0			2.0			2.0	
Link Offset(m)		0.0			0.0			0.0			0.0	
Crosswalk Width(m)		1.6			1.6			1.6			1.6	
Two way Left Turn Lane												
Headway Factor	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02
Turning Speed (k/h)	24		14	24		14	24		14	24		14
Sign Control		Yield			Yield			Yield			Yield	
Intersection Summary												
Area Type:	Other											
Control Type: Roundabout												
Intersection Capacity Utilization 128.7%					ICU Level of Service H							
Analysis Period (min) 15												
Description: Post Office Roundabout												

Table 13: Lanes and geometrics of the Cocoa House roundabout

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	205	151	88	189	156	218	58	213	222	213	164	156
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Lane Width (m)	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Lane Util. Factor	1.00	0.95	0.95	1.00	0.95	0.95	1.00	0.95	0.95	1.00	0.95	0.95
Frt		0.996	0.850		0.991	0.850		0.989	0.850		0.994	0.850
Flt Protected		0.973			0.975			0.990			0.974	
Satd. Flow (prot)	0	1679	1473	0	1674	1473	0	1697	1473	0	1678	1473
Flt Permitted		0.973			0.975			0.990			0.974	
Satd. Flow (perm)	0	1679	1473	0	1674	1473	0	1697	1473	0	1678	1473
Link Speed (k/h)		48			48			48			48	
Link Distance (m)		1717.0			1859.1			1622.0			1128.4	
Travel Time (s)		128.8			139.4			121.7			84.6	
Peak Hour Factor	1.00	1.00	1.00	0.91	0.91	0.91	0.81	0.81	0.81	0.76	0.76	0.76
Heavy Vehicles (%)	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%
Adj. Flow (vph)	205	151	88	208	171	240	72	263	274	280	216	205
Shared Lane Traffic (%)			10%			10%			10%			10%
Lane Group Flow (vph)	0	365	79	0	403	216	0	362	247	0	517	184
Enter Blocked Intersection	No	No	No	No	No	No	No	No	No	No	No	No
Lane Alignment	Left	Left	Right	Left	Left	Right	Left	Left	Right	Left	Left	Right
Median Width(m)		2.0			2.0			2.0			2.0	
Link Offset(m)		0.0			0.0			0.0			0.0	
Crosswalk Width(m)		1.6			1.6			1.6			1.6	
Two way Left Turn Lane												
Headway Factor	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
Turning Speed (k/h)	24		14	24		14	24		14	24		14
Sign Control		Yield			Yield			Yield			Yield	

Intersection Summary

Area Type: Other

Control Type: Roundabout

Intersection Capacity Utilization 100.0% ICU Level of Service G

Analysis Period (min) 15

Description: Jubilee Park Roundabout

Table 14: Lanes, volumes and timings of Jubilee Park roundabout

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Volume (vph)	30	486	27	19	99	30	44	590	213	26	733	36
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Lane Width (m)	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Lane Util. Factor	1.00	0.95	0.95	1.00	0.95	0.95	1.00	0.95	0.95	1.00	0.95	0.95
Frt		0.999	0.850		0.998	0.850		0.995	0.850		0.999	0.850
Flt Protected		0.997			0.992			0.997			0.998	
Satd. Flow (prot)	0	1743	1487	0	1732	1487	0	1736	1487	0	1745	1487
Flt Permitted		0.997			0.992			0.997			0.998	
Satd. Flow (perm)	0	1743	1487	0	1732	1487	0	1736	1487	0	1745	1487
Link Speed (k/h)		48			48			48			48	
Link Distance (m)		1717.0			1859.1			1622.0			1128.4	
Travel Time (s)		128.8			139.4			121.7			84.6	
Peak Hour Factor	0.92	0.92	0.92	0.63	0.63	0.92	0.88	0.88	0.88	0.61	0.61	0.61
Adj. Flow (vph)	33	528	29	30	157	33	50	670	242	43	1202	59
Shared Lane Traffic (%)			10%			10%			10%			10%
Lane Group Flow (vph)	0	564	26	0	190	30	0	744	218	0	1251	53
Enter Blocked Intersection	No	No	No	No	No	No	No	No	No	No	No	No
Lane Alignment	Left	Left	Right	Left	Left	Right	Left	Left	Right	Left	Left	Right
Median Width(m)		2.0			2.0			2.0			2.0	
Link Offset(m)		0.0			0.0			0.0			0.0	
Crosswalk Width(m)		1.6			1.6			1.6			1.6	
Two way Left Turn Lane												
Headway Factor	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
Turning Speed (k/h)	24		14	24		14	24		14	24		14
Sign Control		Yield			Yield			Yield			Yield	

Intersection Summary

Area Type: Other

Control Type: Roundabout

Intersection Capacity Utilization 113.1% ICU Level of Service H

Analysis Period (min) 15

Description: Jubilee Park Roundabout

5. Conclusions

The Post Office and Jubilee Park roundabouts were performing beyond capacities based on the overall volume to capacity ratios of 0.78 and 1.13 respectively. The roundabouts were therefore operatingat intersection capacity utilization (ICU) level of service H and 9% over capacity. The congestion period was in excess of 120 minutes per day. Congruently, the Cocoa House roundabout with volume to capacity ratio of 0.51 and ICU level of service G was also 9% above the traffic-carrying abilities and experiencing congestion periods of 60 to 120 successive minutes.

The 3 roundabouts should be signalized to improve on vehicular movement. Also, the central islands should be channelized by Department of Urban Roads to assist drivers' movement, minimize conflicts as well as increase safety.

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