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Capacity Evaluation of Roundabout Intersections in Khulna Metropolitan City by Using SIDRA

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Abstract

The main emphasis of this study is to evaluate the capacity and Level of Service (LOS) of the roundabouts in Khulna Metropolitan City, Bangladesh. Increasing traffic volumes is the quickly developing major problem facing our modern society. The results of capacity analysis by using SIDRA software indicate that the roundabout has their degree of saturation greater than 0.85. This value is recommended by analysis procedure of some model countries such as Australia, Germany, United Kingdom, and USA, whose roundabouts are designed to operate at no more than 85 percent of their estimated capacity. The LOS is found "F" for the roundabout in Khulna Metropolitan City. Effective capacity versus geometric parameter relationship have been developed in order to find out the causes of their over saturation (V/C >0.85) and the results indicate that number of entry lanes, number of circulatory lanes, high traffic volumes are the major causes of over saturation.

Keywords: *Capacity, Level of Service (LOS), Degree of Saturation, Over Saturation, SIDRA*

1 Introduction

Evaluation of junction capacity is very important since it is directly related to delay, level of service, accident, operational cost and environmental issues. For more than three decades modern roundabouts have been used successfully through the world as an intersection control device (Akcelik, 1997). Therefore, road authorities and other concerned bodies need to conduct a comprehensive capacity and delay study of every roundabouts so that they can come up the solutions for the traffic congestions, traffic delays, level of services, accidents and operating costs. Level of service is a qualitative measure used to relate the quality of traffic service. Level of service is used to analyze highways by categorizing traffic flow and assigning quality levels of traffic based on performance measure like speed, density etc (Papacostas, 2001). Therefore, it is vital to evaluate the capacity of roundabout for proper traffic operation and to give a clear picture for the planners and traffic engineers involved in highway junction design and traffic operation tasks.

1.1 Statement of the Problem

In Khulna Metropolitan City, increasing traffic volumes and congestions are two quickly developing problems facing the society. Now-a-days, it is common to see traffic congestion at junctions at peak hours in the morning and evening. Hence, the traffic police need to intervene in the situation to regulate the traffic flow by over-riding the traffic control devices. Otherwise, it would be practically impossible to have normal traffic flows, especially at roundabout intersections, which is more dependent on driver behavior and balanced traffic flow between the approaches. Poor road planning and sub-standard geometric conditions of roundabouts have a significant effect on roundabout capacity and traffic congestion (May, A.D., 1990). Therefore, it is vital to evaluate the capacity of roundabout for proper traffic operation and to give a clear picture for the planners and traffic engineers involved in highway junction design and traffic operation tasks.

Some of the problems related to capacity of roundabouts are as follows:
a) Necessarily geometric features of roundabouts such as flare and apron do not exist.
b) In some roundabouts, there are visibilities problems caused by plants or elevated masonry. This causes the entering driver to hesitate on entering the circulating traffic, affecting the capacities of the roundabouts.
c) Roundabouts central islands are accessed by pedestrians.

d) Absence of road markings, signings and lightings.

1.2 Objectives of the Study

The objectives of this study are given below:
a) To compile available information regarding capacity analysis of roundabouts through critical literature review.
b) To select the appropriate methodology for evaluating the capacity of roundabout in Khulna Metropolitan City.
c) To evaluate the capacity of roundabout in Khulna Metropolitan City.
d) Based on the results of the analysis to draw conclusions and recommendations for possible future considerations during roundabout's design.

2 Methodology

To achieve the objectives of this study, roundabout's traffic data at peak period and geometric data were required. The geometric data should be measured correctly since geometric design will improve not only capacity but also safety, which is major concern for road design. As much as possible, the traffic data collected should indicate the existing peak hour traffic conditions. It is necessary to collect traffic data using skilled persons and by assigning them at the roundabouts.

2.1 Location Survey

There are around three major roundabouts in Khulna Metropolitan City, and their size more or less is related to their leg numbers. The three roundabouts were namely Shibbari Roundabout, Hotel Royal Roundabout, and Moilapota Roundabout. The location survey was conducted at Shibbari roundabout in Khulna Metropolitan City. This roundabout was chosen based on the principle of possible representative of the target population of the roundabouts in terms of size and numbers. All the roundabouts in KMC are more or less similar to each other, so the roundabout can represent all the roundabouts in the city.

2.2 Geometric Data Collection

According to the SIDRA software for capacity and delay analysis, the geometric data was collected including number of circulatory lane, island diameter, circulatory roadway width, inscribed circle diameter, entry lane number, average lane width at entry, entry angle and entry radius. These data was collected from Khulna Development Authority (KDA). The collected geometric data are summarized in Table 1and Table 2.

Table 1. Summary of intersection geometry

Sl No.	Roundabout Name	No. of Legs	number of circulatory lane (m)	island diameter (m)	circulatory roadway width (m)	inscribed circle diameter (m)
1	Shibbari	4	3	19	17	36

Table 2. Summary of legs or approaches geometry

Sl No.	Roundabout Name	Leg Name	Number of Entry Lane	Average Lane Width (m)	Entry Angle	Entry Radius (m)
1	Shibbari	KDA Avenue	2	5.9	71	9
		Ibrahim Mia Road	1	3.4	55	31
		Mojid Sharoni	2	3.4	53	3
		Khan A Sobur Road	2	7.9	51	13

2.3 Traffic Data Collection

The movement of traffic vehicles and their volume are important parameters in capacity analysis for using SIDRA software. Thus traffic volume data was collected at peak periods for a period of one hour (60 minutes) on working day of sunny weather with their direction of movements. Traffic volume was collected for each separated lanes. Traffic data was collected by using a video camera. Since traffic volumes plays most important

role in capacity and delay analysis, so it is important to collect the traffic data correctly. The volume of each type of vehicles is summarized in Table 3.

Table 3. Vehicle volume at intersections at peak hour (4.30pm to 5.30pm)

Round-about Name	Heavy Vehicles			Light Vehicles									Total Traffic (PCU)	% of Heavy Vehicle
	Bus	Truck	Total	Car	Pick up	Micro Bus	Jeep	Rick- shaw & Easy bike	Van	Motor cycle	Bi-cycle	Total		
Shib-bari	16	27	43	108	12	34	10	820	1187	272	166	2609	3569	4

From Table 3, it is found that the percentage of heavy vehicles is not more than 4 percent and the light vehicles volume is larger than the heavy vehicles volume. The traffic volume in passenger car unit and the movement of the traffic on each approach leg are also essential for the analysis. The passenger car equivalent factors are used to convert the number of vehicles in passenger car unit. The Passenger Car Unit (PCU) values given in the geometric design of Highways (MoC, 2001) are given in Table 4.

Table 4. PCU of different types of vehicle in Bangladesh

Vehicle Categories	PCU
Passenger Car	1.00
Light Good Vehicle	1.00
Truck	3.00
Bus	3.00
Auto-rickshaw/Motorcycle	0.75
Rickshaw/Van	2.00
Bicycle	0.50

The summarized entry traffic flow on roundabout approach legs are shown in Table 5. From Table 5, it is observed that the traffic flow is unbalanced at legs or approaches at the roundabout. However, it is not recommended to design roundabout as traffic control devices when the traffic flow is unbalanced at different legs (FHWA-RD-00-067, 2000).

Table 5. Summarized entry traffic flow on roundabout approach legs

Sl No	Roundabout Name	Leg Name	Entry Traffic On Legs (PCU)	Percentage of Traffic Share
1	Shibbari	KDA Avenue	790	22
		Ibrahim Mia Road	637	18
		Mojid Sharoni	915	26
		Khan A Sobur Road	1227	34

3 Results and Discussions

Considering all the stated summarized data, it is possible to analyze the capacity of the roundabout using SIDRA software. However, some additional data are also required to evaluate the capacity of the roundabout and driver behavior. The Environmental Factor represents the general roundabout environment in terms of roundabout design type, visibility, significant grades, operating speeds, size of light and heavy vehicles, driver aggressiveness and alertness (driver response times), pedestrians, heavy vehicle activity (goods vehicles, buses or trams stopping on approach roads), parking turnover and similar factors a movements on approach and exit sides as well as the circulating road as relevant.

3.1 Results

The results obtained by using SIDRA software is discussed in this section. The summarized capacity analysis results are shown in the Table 6. The performance of the roundabout is measured with the degree of saturation or V/C ratio and the level of service (LOS) is also applied according to United States Highway Capacity Manual (US HCM). Environmental Factor can be used to calibrate the capacity model to allow for less restricted (higher capacity) and more restricted (lower capacity) roundabout environments. A value in the range o.50 to 2.00 can be specified (standard default = 1.0; default of the US HCM models when the SIDRA Standard capacity model is used = 1.2).

Table 6. Summarized capacity analysis results on the intersections

Sl No.	Roundabout name	Total Vehicle Flow (PCU)	Effective Capacity (vehicle/h)	Degree of Saturation (V/C)	Average Delay (sec)	Level of Service (LOS)
1	Shibbari	3569	1880	1.999	247.3	F

From Table 6 it is observed that the Shibbari roundabout has the lowest degree of saturation and the level of service (LOS) is F. For the Shibbari roundabouts, lane by lane capacity has been carried out and capacity at legs, degree of saturation and opposing flow has been summarized. The summarized capacity analysis results on the approaches or legs are shown in the Table 7.

Table 7. Summarized capacity analysis results on the approaches or legs

Sl No.	Roundabout Name	Leg Name	Entry Traffic On Legs (PCU)	Opposing Circulatory Flow	Degree of Saturation (V/C)	Capacity at Legs	V/C> 0.85
1	Shibbari	KDA Avenue	790	497	0.913	632	0.063
		Ibrahim Mia Road	637	512	1.999	646	1.149
		Mojid Sharoni	915	677	1.684	379	0.834
		Khan A Sobur Road	1227	995	0.746	452	0.104

By observing the V/C > 0.85 column of Table 7, which is based on US HCM, it is easy to identify the legs which are in critical condition. Table 8 shows the legs with critical condition.

Table 8. Legs with critical condition (V/C > 0.85)

Sl. No.	Roundabout Name	Leg Name
1	Shibbari	Ibrahim Mia Road

Before the investigation of the reason for their inadequacy, it is better to see the assumption on the theory in respect of direct relationship of capacity at legs and opposing circulatory flow, and number of circulatory lane and circulatory flow. Capacity at legs is influenced by average entry lane width and number of entry lane.

Table 9. The Rearranged table from Table 7 using numbers of entry lanes and circulatory lanes

Sl. No.	Roundabout Name	Leg Name	Number of Entry Lane	Number of Circulatory Lane	Entry Traffic On Legs (PCU)	Opposing Circulatory Flow	Capacity at Legs	V/C
1	Shib -bari	KDA Avenue	2	3	790	497	632	1.250
		Ibrahim Mia Road	1		637	512	646	0.986
		Mojid Sharoni	2		915	677	379	2.414
		Khan A Sobur Road	2		1227	995	452	2.715

3.2 Conditions of Roundabout

It is possible to identify the problems of the approaches using Table 7 which shows V/C > 0.85, entry traffic volume at legs, traffic volume of circulatory flow at legs and circulatory lane numbers and charts. Table 10 shows the summary of the conditions of the roundabout.

Table 10. Summary of the conditions of the roundabout

Sl No.	Roundabout Name	Leg Name	Problems
1	Shibbari	Ibrahim Mia Road	Circulatory lane number is not adequate.

4 Conclusions and Recommendations

The capacity analysis of the selected roundabout namely Shibbari Roundabout is conducted by using SIDRA and some major problems are encountered at the roundabout. The conclusions and recommendations of this study are given below:

4.1 Conclusions

From the results of the capacity analysis of the Shibbari roundabout in Khulna Metropolitan City, it is found that the roundabout is in serious problems. Over saturation is the most common problem of the roundabout. Based on the observed field conditions, it is common to observe that at the peak hours, the traffic police have to regulate the traffic at the roundabout. The study showed that the major problems are related to the number of entry lanes, number of circulatory lanes, high traffic flow and unbalanced traffic on the approaches which in fact, not recommended on the roundabout. Besides, the roundabout is built when the traffic flow was lower and without considering future traffic extension.

Even if modern roundabouts driving rules are to be applied to Khulna Metropolitan City roundabouts, some of the most important geometric elements such as deflection, proper island splitters etc. don't exist in the roundabouts of the Khulna Metropolitan City namely Shibbari roundabout. Deflection is the most important geometric element, which forces drivers to reduce their speeds and avoid collision between neighboring legs entering vehicles. The splitter islands on the roundabout approaches provide cues to the driver as to the angle and radius of approach on the entry to the roundabout.

All the geometric data used to input parameters for empirical method capacity analysis do not exist at Khulna Metropolitan City roundabouts, thus, only analytical method was the option to carry out the capacity analysis with some geometric elements by using SIDRA.

4.2 Recommendations

The geometric data of the roundabout of the Khulna Metropolitan City was collected from KDA by considering the rules of geometry. So it is recommended to revise the geometric data of the roundabout and to build up the essential geometric elements properly as stated in the design manual of modern roundabout since they are very helpful to have reasonable capacity and traffic safety.

The collected traffic data of the roundabout at peak hours have high and unbalanced traffic flow and many legs of the roundabout are found to be over saturation of traffic flow. It is recommended to increase the number of entry lanes, the number of circulatory lanes and the width the entry lanes.

At Shibbari Roundabout, the entry traffic flow was found 3569 PCU, which is very high to be accommodated by the roundabout.

In this study, pedestrian traffic volume cannot be considered because of the time limitations. So it is recommended to include pedestrian traffic volume in the capacity analysis of the roundabout by using SIDRA since it affects greatly the normal traffic flows and the capacity of the roundabout.

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