Quantitative Analysis of Queue Length of Falah Roundabout (UAE, Sharjah)

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Abstract—Roundabouts have faced a huge development in terms of designing and operation, the reason behind that is to get the most safe and functional design. The functionality is affected by different factors e.g. line width, diameter of the roundabout…etc., when the capacity of the roundabout is fully utilized, queue length starts to form in the different approaches, which indicates of a minor or major issue that should be studied.

This paper discusses the different factors affecting the queue length of an approach on the roundabout (Al Falah roundabout), after obtaining the data, regression analysis was done to provide a model that can be used for estimating the volume capacity ratio from queue lengths or vice versa. Two other methods were used to compare the obtained model (HCM 2010 Method and Two Minute Rule Method), in addition to a field data collection of the actual timing needed to pass that queue length, which was assigned as the true value of the models and comparing depending on it.

Finally, the discussion of the term paper, will include the different concepts of advanced statistical analysis, the will (as expected) contain different types of distributions and the coloration between the keys of the roundabouts design, and will study the limitation and how it can be improved in future.

Keywords—Queue Length, Delay Time, Volume Capacity Ratio, Two Minute Rule, HCM and Two Minutes Methods.

I. Introduction

All A roundabout is a form of circular intersection in which traffic travels around a central island and in which entering traffic must yield to circulating traffic. Traffic circles have been part of the transportation system in the United States since at least 1905 when one of the first circles, known as the Columbus Circle in New York City, was designed by William Phelps Eno. The prevailing designs enabled high-speed merging and weaving of vehicles. Yet, high crash experience and congestion in the circles led to rotaries falling out of favor in America after the mid-1950s. Internationally, the experience with traffic circles was equally negative, with many countries experiencing circles that locked up as traffic volumes increased. The modern roundabout was developed in the United Kingdom to rectify problems associated with these traffic circles. In 1966, the United Kingdom adopted a rule at all circular intersections that required entering traffic to give way, or yield, to circulating traffic. This rule prevented circular intersections from locking up by not allowing vehicles to enter the intersection until there were sufficient gaps in circulating traffic. In addition, smaller circular intersections were proposed that required adequate horizontal curvature of vehicle paths to achieve slower entry and circulating speeds. These changes improved the safety characteristics of the circular intersections by reducing the number and the severity of crashes. The modern roundabout represents a significant improvement, in terms of both operations and safety, when compared with older rotaries and traffic circles. Therefore, many countries have adopted the modern roundabout as a common intersection form, and some have developed extensive design guides and methods to evaluate the operational performance of modern roundabouts, one of them is the queue length, which a queue due to the accumulation of vehicles at one approach or more, due the capacity of the roundabout and merging volumes of vehicles, and that main parameter will be studied for Al Falah Roundabout, located in Sharjah, United Arab Emirates (345251.62 m Easting and 2800120.63 m Northing), for the North East approach.

The main objectives of this paper are:

A. To get a representative data for the delay, queue lengths, volumes and capacities of the vehicles at the roundabout.
B. Develop a regression model for the queue length that can be applied in the region.
C. Compute the theoretical queue length from two methods HCM 2010- and Two-minutes method.
D. To compare between the three models results and the actual calculated field data.

II. Literature Review

Queue length is important when assessing the adequacy of the geometric design of the roundabout approaches. The estimated length of a queue can also provide additional insight into the operational performance of a roundabout in comparison to other intersection types. Queue interaction with adjacent intersections or driveways is another important consideration. each lane should be checked against available storage. The queue in each lane may interact with adjacent lanes in one or more ways: • If queues in adjacent lanes exceed available storage, the queue in the subject lane may be longer than anticipated due to additional queuing from the adjacent lane. • If queues in the subject lane exceed the available storage for

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adjacent lanes, the adjacent lane may be starved by the queue in the subject lane. Should one or more of these conditions occur, the analyst can conduct a sensitivity analysis using the methodology by varying the demand in each lane. The analyst may also use an alternative tool that is sensitive to lane-by-lane effects, as discussed in Section 4.6 of this chapter. Author names and affiliations are to be centered beneath the title and printed in Times New Roman 12-point, non-boldface type. (NCHRP 2010).

However, a research paper from University of Trieste, done by R. Camus, M. Dall'Acqua and G. Longo, studied the capacity and the queue length on a un-signalized roundabout, and their outcomes were: that development of a different approach to roundabouts analysis seems to be necessary to overcome the uncertainty in roundabouts evaluation due to many different models existing in literature. Their methodology could be a general framework for roundabout performance evaluation because:

1- It is in accordance with the HCM main principles regarding the merge area analysis and, at the same time, the methodology is in well accordance also to the Gap Acceptance theory, which is the well-known theoretical approach to the un-signalized intersections analysis;

2- Comparative results show that the developed model could easily cover capacity prediction results of both the two considered German models (linear model, macroscopic approach and exponential model, microscopic approach), belonging to the called Statistical and Probabilistic approaches respectively, with reference to the global capacity of the roundabout and to the single approach entry capacity

And they stated also that their model could be improved by including the average total delay estimation for each vehicle grouped by entry and exiting leg (O/D flows). Total delay main part is given by queuing delay on single-lane small roundabouts, but on multilane roundabouts also the geometric delay must be included in the total delay computation. In such a case, it should be necessary to include also the weaving and diverging movements for a more complete roundabout performance analysis. (R. Camus, 2004).

III. Methodology

The steps of collecting the volumes of the vehicles and the queue length were as follows:

Two observers had an internet connected smart phones, one at the roundabout entrance of the selected approach for study, and the other is moving along with the increasing or decreasing queue length, both their phones were connected to each other, so the total distance between them can be obtained accurately, which was assigned to be the queue length.

On the entrance of the roundabout, camera was placed to record the merging flow, then was used to count the number of vehicles, a sign was given to the camera that this is the time of computing the queue length, so later they can be related to each other.

More site experiment where done is by going by own car and stand in the same queue length several times, to count how long it takes, to cover a certain know distance and volume, which helped in estimating the real and true model.

IV. Data Collection

The Time where the data was collected was at 7:00 am to 9:00 am and 3:00 pm to 5:00 pm, on both Monday and Wednesday, with a time offset of 15 minutes between each reading, which lead to 32, each point has the volume of vehicles in that 15 minutes, in addition to the queue length, including the geometry data, and they were sorted as follows:

TABLE I: DATA COLLECTION ON MONDAY

Day of observation	Time frame	Time (min)	Volume	Queue length(m)
MONDAY	7:00am-9:00am	30	57	30.8
		45	69	30.1
		60	84	40.5
		75	66	49.6
		90	90	51.7
		105	67	76.5
		120	55	90.2
	3:00pm-5:00pm	15	125	563.45
		30	127	576.3
		45	128	598.24
		60	126	590.6
		75	129	578.5
		90	133	598.24
		105	134	567.8
		120	127	567.32

TABLE II: DATA COLLECCTED ON TUESDAY

Day of observation	Time frame	Time (min)	Volume	Queue length(m)
MONDAY	7:00am-9:00am	15	27	8.39
		30	59	23.27
		45	69	29.65
		60	86	43.39
		75	88	45.3
		90	91	48.31

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		105	68	28.97
		120	57	22.12
	3:00pm-5:00pm	15	126	100.85
		30	129	107.38
		45	133	116.74
		60	132	114.33
		75	129	107.38
		90	133	116.74
		105	127	102.98
		120	130	109.65

TABLE III: ACTUAL COLLECTED TIME TO PASS

Queue Length (m)	V/C Ratio	Time To pass (s)
192.7	0.57	11.5
308.4	0.68	18.5
523.5	0.78	31.5

V. Results

AAfter getting the data, the HCM 2010 method of estimating the queue length was followed, in addition to the two-minute rule for estimating the queue length (from: The Analysis Procedures Manual (APM) which provides the current methodologies, practices and procedures for conducting long term analysis of Oregon Department of Transportation (ODOT) plans and projects.), and they will be compared for their applicability in the region, the final calculations done to obtained the expected queue length form the described methodologies, table 4 illustrates those measures and calculations.

TABLE IV: CALCULATED PARAMETERS FROM THE COLLECTED DATA

ACTUAL MEASURED			CALCULATED METHODS			
Volume	Capacity	Queue length(m)	X=V/C	Delay (s)	Queue length using Two Minutes Rule (veh)	Queue length using HCM (veh)
25	167	23.5	0.15	107.09	97	7.67
27	167	22.9	0.16	104.35	110	8.39
55	167	90.2	0.33	292.54	426	21
57	167	30.8	0.34	130.45	220	22.12
57	167	90.15	0.34	292.37	220	22.12
59	167	30.71	0.35	130.05	220	23.27
66	167	49.6	0.52	182.2	508	44.34
67	167	76.5	0.4	248.33	522	28.29
68	167	75.71	0.41	245.75	261	28.97
69	167	30.1	0.41	121.75	261	29.65
69	167	29.15	0.41	117.9	261	29.65
84	167	40.5	0.5	162	412	41.54
86	167	40.23	0.51	160.9	316	43.39
88	167	48.77	0.53	179.15	330	45.3
90	167	51.7	0.54	177.26	453	47.29
91	167	51.55	0.54	176.73	343	48.31
125	167	563.45	0.75	1465.35	508	98.76
126	167	590.6	0.75	1567.6	1043	100.85
126	167	562.72	0.75	1761.57	1043	100.85
127	167	576.3	0.76	1773.23	1057	102.98
127	167	567.32	0.76	1595.59	1057	102.98
127	167	567.49	0.76	1634.37	1057	102.98
128	167	598.24	0.77	1794.72	1057	105.16
129	167	578.5	0.77	1735.5	1070	107.38
129	167	575.37	0.77	1770.38	1070	107.38
129	167	577.99	0.77	1733.96	1070	107.38
130	167	566.84	0.78	1594.23	1084	109.65
132	167	590.29	0.79	1770.87	1139	114.33
133	167	598.24	0.8	1765.3	1098	116.74
133	167	597.94	0.8	1793.82	1098	116.74
133	167	597.76	0.8	1763.89	1098	116.74
134	167	567.8	0.8	1389.55	1111	119.2

VI. Modeling

A lot of regression models was tested to reach the optimum R^2 of the model, and the most accepted one was using the following parameters and their regression models:

$$\text{Delay} = \frac{100}{\ln(\text{Delay})} \quad (1)$$

$$X = \frac{\text{Volume}}{\text{Capacity}} \rightarrow \log_{10}(x) * \ln(\text{Volume}) \quad (2)$$

$$\text{Queue Length} = \log_{10}(\text{Queue Length}) \quad (3)$$

And obtained the following parameters:

$$R^2 = 0.9962, \text{Intercept} = 0.16, \text{Delay} = 0.013, x = 0.0725$$

The final model equation generated:

$$Log(QL) = -0.126\left(\frac{100}{\ln(Delay)} + 0.209 * (\log_{10}(x) * \ln(V))\right) + 4.51 \quad (4)$$

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Plotting charts as results will help in estimating the models of each involved method and their final output was as shown in Figure 1 to 5:

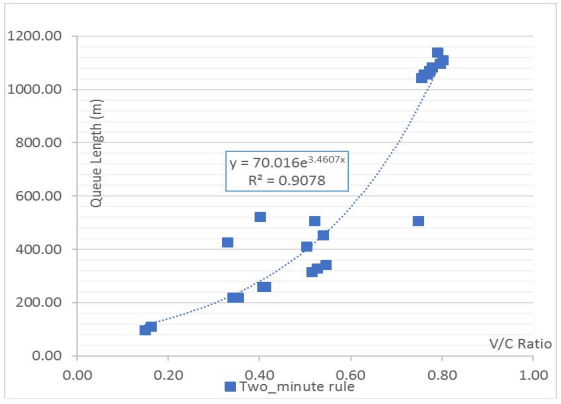


Fig 1: Two- Minute Model Comparison v/c Ratio vs Queue Length

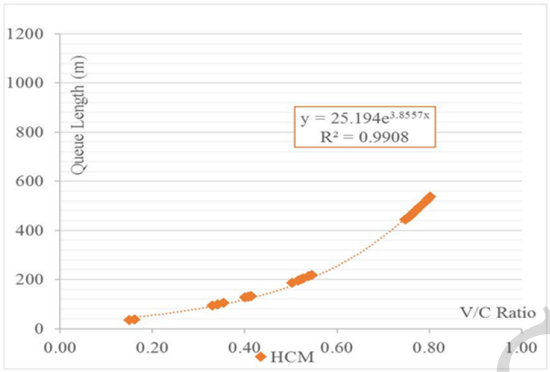


Fig 2: Roundabout Model Comparison v/c Ratio vs Queue Length

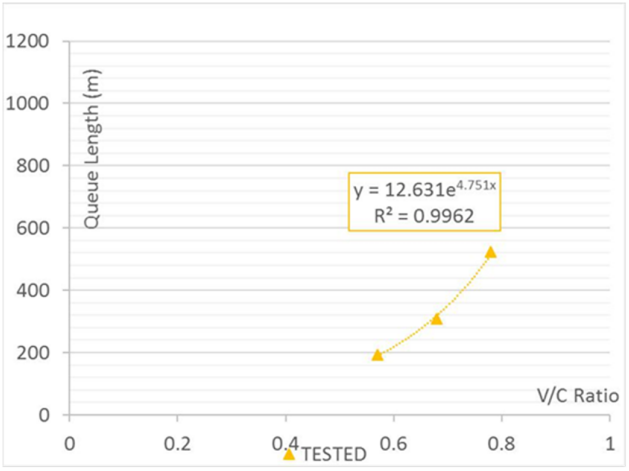


Fig 3: Actual Tested Queue Length vs V/C Ratio

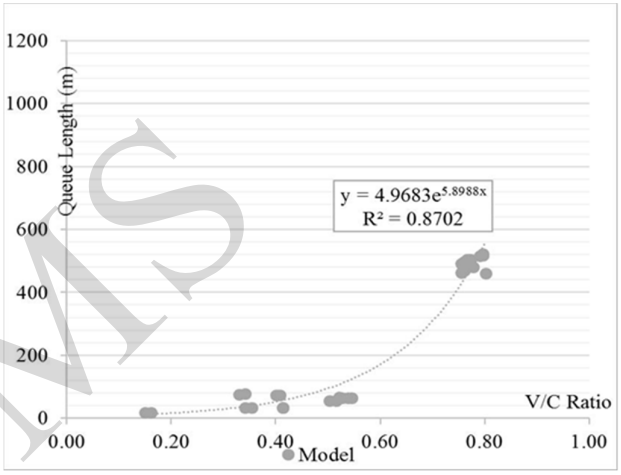


Fig 4: HCM 2010 Model Comparison v/c Ratio vs Queue Length

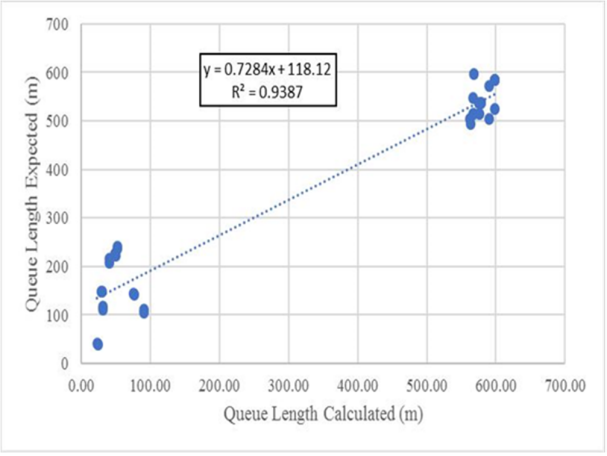


Fig 5: Expected Queue Length vs Actual Queue Length

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VII. Summarized results and discussion

TABLE V: FINAL COMPUTED MODELS AND EQUATIONS

METHOD	EQUATION OBTAINED	R^2
TWO MINUTES RULE	$QL = 70.016\, e^{3.4607\left(\frac{v}{c}\right)}$	0.9078
HCM	$QL = 25.194\, e^{3.8557\left(\frac{v}{c}\right)}$	0.9908
MODEL	$QL = 12.631\, e^{4.751\left(\frac{v}{c}\right)}$	0.9962
TESTED	$QL = 4.9683\, e^{5.8988\left(\frac{v}{c}\right)}$	0.8702
ACTUAL VS EXPECTED		0.9387

As observed from the final obtained graphs, the two minutes method of estimating the queue length highly overestimates the actual length, for the same v/c ratio of the model, however, the other two methods of estimating are much close to the actual obtained data from the site, and they have been discussed from different perspective and characteristics as follows:

A. HCM Method:

There were some factors that weren't considered in estimating the models, so the square of residuals shouldn't be high, but as was shown before the was observed to be high (0.9908), and the reason behind that is any undetermined factor(s) were assigned as neutral coefficient(s), so the points were converged to one specific increasing intervals, in terms of exponential increasing.

B. Regression Model:

The regression model was obtained depending on the actual and only actual factors that could be collected in the field, but it should be done for more than one intersection or roundabout, and that to include more changings in the factors (line width, roundabout diameter …etc.), and that indicated the higher square of residuals obtained (0.9962). And to justify the high value if regression model, is that the number of factors used were low from the begging and not high changeable, because they physically depend on each other.

C. Test Model:

The three values that have been obtained from the test have been plotted and studied in terms of changing with respect to the different variables, it shows a square of residuals of 0.8702, which is relatively low comparing to the other models, and that's because the data points have been done were very few comparing with the others methods, and the factors included are lesser, however, this model can be considered as the true value because it is the actual durations, lengths, and volumes in the approach under study in the roundabout.

D. Actual vs Expected:

The comparison between the expected and actual computed queue lengths, showed a slope line of 0.728 with difference of 0.272 from the 45 degrees slope, however this indicates the model needs more improvement in terms of included factors, or the HCM model need to be calibrated to fit the existing conditions of our region.

VIII. Future prospects

Four approaches of the roundabout shall be studied, and a general equation depending on time to be developed.

Roundabouts will be categorized and put under certain equations or models, to help in predicting existing or future expected queue lengths or congestions on the roundabouts.

IX. Conflict of interest

None.

X. Conclusion

In summary, the queue length at Falah roundabout was studied in terms of the hanging with respect to the volume capacity ration, using 3 approaches, (HCM 2010, Two-minute rule and a regression model), then have been compared to each other and the actual data in the field. Two minutes rule overestimates the actual queue length, HCM 2010 is much accurate than it, but it underestimated the actual field data, while the regression model was suitable (overestimated by smaller deviation comparing with the other two methods). In future, the HCM 2010 method can be improved to meet the current region factors, so it can be used in different roundabouts, depending on certain characteristics of it. In addition to including more variables to be included in the study, to get a more realistic and accurate approach of the actual existing model.

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