Case Study Investigation of Traffic Circle Capacity

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A capacity analysis of Latham Circle, a traffic circle in New York State, is presented. From videotapes, 1-min observations of entry flow are correlated with simultaneous observations of circulating flow. Values for the minimum acceptable gap, minimum circulating headway, move-up time, and so forth are calculated so that the predictions of various capacity equations, established abroad, can be compared and contrasted with the traffic circle's performance. It is found not only that the observed parameter values closely match those from abroad, but also that several of the equations appear to provide reasonable estimates of capacity. Because of this, these relationships may be adaptable to U.S. conditions without significant recalibration or reformulation.

Internationally, there has been a resurgence of interest in traffic circles. Germany (*1*), Switzerland (*2,3*), France (*4,5*), Australia (*6*), Norway (*7*), and Israel (*8*) are among the countries experimenting with their use. The United States, however, has had few recent instances in which these traffic control devices have been installed (*9*).

The idea of the traffic circle dates to about 1903, when Henard suggested the concept as a form of traffic control at busy junctions (*10*). The first traffic circle was Columbus Circle, constructed in New York in 1905 (*11*). Two years later two more were built in Paris at the Place de l'Etoile and Place de la Nation (*11*). The operating principle of these facilities is that conflicting vehicles merge, weave, and diverge, at a relatively uniform speed, as they circulate about a central island.

DEFINING TRAFFIC CIRCLE CAPACITY

When traffic circles were introduced, their operation was governed by the on-side priority rule, wherein circulating vehicles gave way to those entering. This practice was an extension of the prevalent operating rule, still in use today for uncontrolled intersections, wherein motorists on the left yield to those on their right (*12*).

The on-side priority rule produced an operating discipline similar to that for weaving sections. Wardrop, and others, found that capacity equations based on weaving principles could be derived (*13*). Generally, as volumes increased, wider and longer weaving sections were required, as was a bigger central island.

Eventually, however, the on-side priority rule led to traffic lockups. Vehicles in the traffic circle came to a standstill because they were blocked by downstream entryway flows. To prevent these conditions, the off-side priority rule was introduced. Vehicles on the entry legs were required to yield to those already in the circulating flow. This produced queues on the entry legs but kept the facility's operation from reaching a standstill.

Shifting to the off-side priority rule also led to changes in traffic circle operation, as one might expect. Entryway junctions behaved more like T-intersections, with the entering vehicles searching for and accepting gaps in the circulating flow. Analysts found it necessary to redefine capacity as the maximum entryway flow rate achievable for a given level of circulatory flow, as shown in Figure 1. From the work by Tanner and by Kimber (*14, 15*), capacity equations were developed that postulated an exponential relationship between the two flows. These relationships, and the linear geometric formulas developed by Kimber (*16*), are used here to analyze the performance of Latham Circle, a traffic circle.

As shown in Figure 2, if one defines the term "throughput" as the pairwise combination of circulatory and entryway flows for a given time period, these capacity equations predict the maximum combinations that are possible, establishing a trade-off surface between circulating and entryway flows. Hence, the issue for Latham Circle is as follows: do any of the capacity equations developed abroad provide a plausible upper bound on the throughput values observed?

SITE DESCRIPTION

Latham Circle is at the junction of New York State Route 2 [annual average daily traffic (AADT) = 19,430] and U.S. Highway 9 (AADT = 21,140) in Latham, New York. Built in 1949, it has been studied heavily before, in 1952 (*17*). Lying northeast of Albany, next to Latham Circle Mall, it is in the midst of a large commercial area that parallels Interstate 87. The facility serves both commuter and shopping trips.

Except for its diameter, the circle is designed much like a modern-day traffic circle (*1,6,18*). It has a two-lane circulating roadway and two-lane entrances and exits. There are four legs and an underpass, built in 1957, for through traffic in the north-south direction (on US-9). The central island has an inscribed diameter of 83 m, all the lanes are nominally 3.65 m wide, and the angle of deflection on entry is approximately 35 degrees. The traffic circle operates under the off-side priority rule since there are stop signs on the US-9 entrances and yield signs on the NY-2 entryways. A wide island separates the entrances and exits on US-9, and splitter islands are present on NY-2. Limited flaring exists on all entryways.

DATA COLLECTION

Data collection for the capacity analysis was two-pronged. First, general information about the site was obtained from New York

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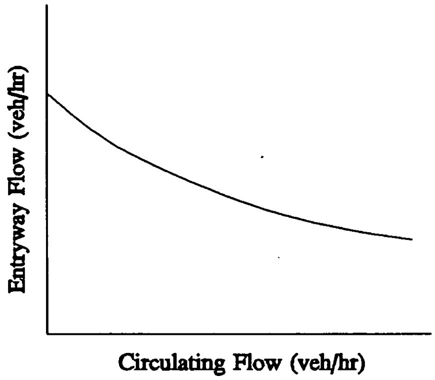


FIGURE 1 Capacity relationships for traffic circles.

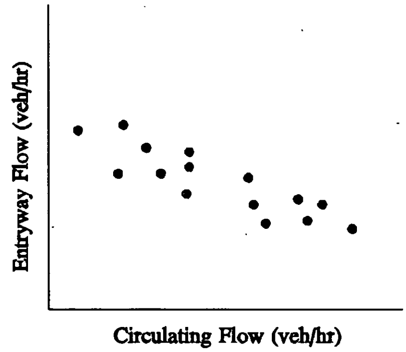


FIGURE 2 Facility throughput: combinations of entryway flow and circulating flow.

State Department of Transportation's Region 1 offices (e.g., plans for the circle, accident statistics, and AADTs). Then the circle's traffic flows were videotaped under peak-hour conditions, the first phase of recording occurring on March 7 and the second phase on April 23, 1992.

The three busiest entryways—eastbound, northbound, and southbound—were taped on March 7 for approximately 20 min each; the busiest of these (the northbound entrance) was taped on April 23 for another 1 hr. In the text that follows, these are called the Group 1 through 4 data sets: Group 1 is the data for the eastbound entrance on March 7; Group 2, the northbound entrance that same day; Group 3, the southbound entrance that same day; and Group 4, the northbound entrance on April 23. Even though the data for Groups 2 and 4 pertain to the same approach, they have been kept separate to enable informal testing for consistency in the observed behavior of a given site.

From the site plans, geometric information was extracted for later use in the capacity formulas. From the videotapes, 1-min observations of traffic flows were developed, as well as estimates of the average minimum critical gap, the minimum circulating headway, and the follow-up time. (There will be more discussion about these efforts later.)

FINDINGS

Of greatest interest is the capacity of the traffic circle. Figure 3 shows a plot of the 1-min entryway flow rates against their corresponding circulating flow rates for the four groups of data, creating a picture of the circle's throughput characteristics. The upper range of these throughput combinations reflects the capacity characteristics of the facility. Although an obvious trend is not apparent, it is clear that the peak-hour circulating flow ranges between 500 and 1,500 vehicles per hour (vph) and the entryway flow ranges between 400 and 1,000 vph. The maximum entering flow rate tends to decrease as the circulating flow rate increases, as would be predicted by the capacity equations developed abroad.

Differences among the approaches are also apparent. The northbound approach (Groups 2 and 4) has its observations clustered in the upper right-hand portion of the graph, which makes sense because that approach is the busiest. The data points for the eastbound approach (Group 1) primarily sit in the upper left-hand portion of the graph, reflecting the predominance of heavy entering traffic. Finally, most of the data points for the southbound entrance (Group 3) are in the bottom left-hand corner of the graph, which is logical since that location has the smallest flows on both the entryway and the circulating roadway.

As for gap parameters, the time headway between circulating vehicles, τ, appears to lie in the range of 0.7 to 1.2 sec, as shown in Table 1. To determine this, the videotapes were processed to identify uninterrupted sequences of circulating vehicles passing by each of the entryways. Of greatest interest were the more tightly grouped of these sequences, which represent "bunches" of traffic. [Troutbeck (*6*) further discusses bunching.)

To estimate τ, these data were sorted and summarized, as shown in Figure 4, producing cumulative density functions (CDFs) by group. It is clear that the CDFs for Groups 2 and 4 are nearly identical, as should be the case since they are for the same entryway. The CDF for Group 3 is more sloped and skewed to the right, which makes sense because the circulating traffic of the southbound approach is more dispersed with fewer bunches (*18*). The CDF for Group 1 is also skewed to the right, which should be the case since the eastbound entrance (Group 1) sees nearly the same dispersed circulating traffic flow as does the southbound approach (Group 3).

Figure 4 also reinforces the validity of using 0.7 to 1.2 sec for τ. This range encompasses the spread of 5th- and 10th-percentile values observed. It also matches with values observed abroad, as in the 1- to 2-sec value cited by Austroads (*18*), the 1.17 sec found by Armitage and McDonald (*19*), and the nominal 2-sec value (per lane) prescribed by Bennett (*20*).

The proportion of free vehicles in the circulating traffic stream, α ($0 \leq \alpha \leq 1$), appears to lie in the range of 0.4 to 0.7. As Table 2 indicates, the specific values by group are 0.62, 0.51, 0.73, and 0.38, respectively, based on the number of vehicles that are not in platoons with average headways of 2 sec or less. The table also gives comparable values for a 3-sec criterion and values derived from the tables provided by Austroads (*18*).

The average minimum acceptable gap or critical gap, t_a, appears to lie between 2.8 and 4.0 sec, as presented in Table 3. Similarly, the follow-up time, t_f, is between 1.8 and 3.7 sec. (These values are for the two entry lanes combined—90 percent or more of the traffic uses just the right-hand-most lane.) The methods of Armitage and McDonald (*19*) and of Siegloch (*21*) were used to estimate these parameters. Close matches exist not only among the values for the different groups but also between the values developed by the two methodologies. This suggests consistency in driver behavior, regardless of which approach is being used, and consistency between the two estimation methodologies.

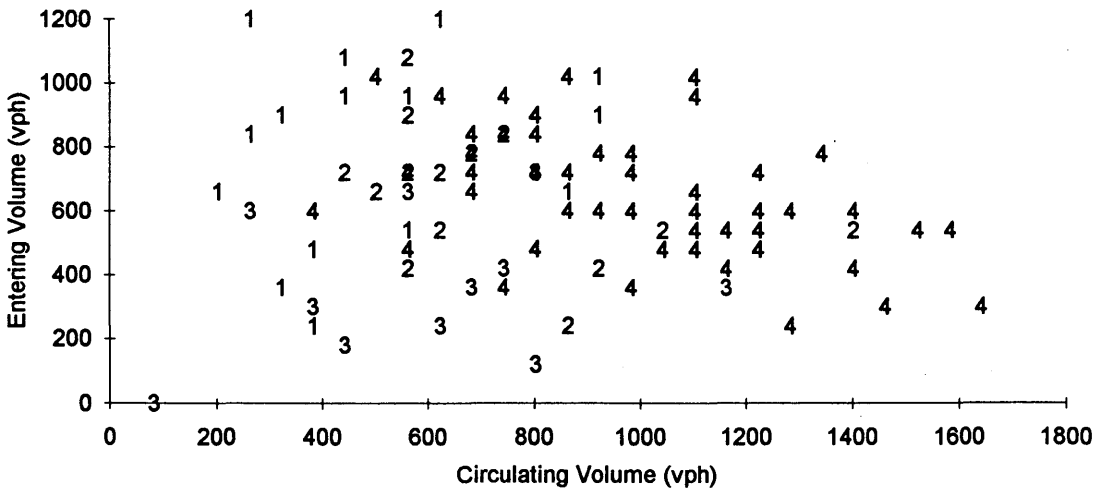


FIGURE 3 Throughput observations: peak-hour conditions, all groups.

TABLE 1 Gap Data for Bunches of Circulating Vehicles

Group	Number of Observations		Observed Gaps for Following Vehicles				
	Bunches	Following Vehicles	Minimum	5th Percentile	10th Percentile	Median	Mean
1	26	55	0.38	0.72	1.10	2.09	2.89
2	41	103	0.99	1.33	1.38	1.95	2.04
3	26	63	0.83	1.21	1.37	2.48	2.87
4	172	605	0.61	1.09	1.18	1.68	1.77

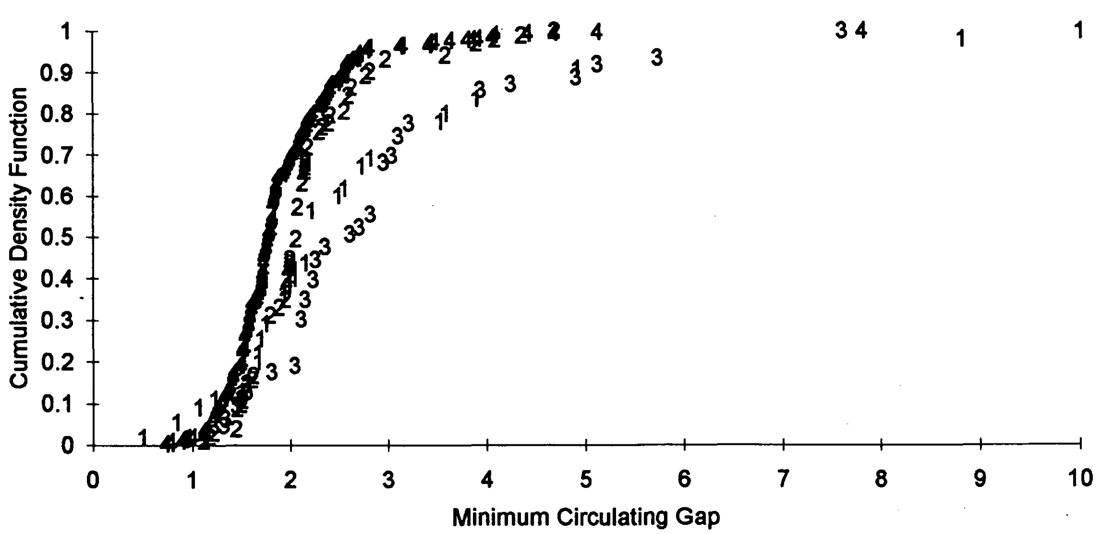


FIGURE 4 Circulating gap cumulative density functions.

TABLE 2 Percentage of Free Vehicles

Group	Observed Volumes		Estimated Values[1]		Suggested Values from (4) [2]	
	Q_c	Q_e	2-sec	3-sec	$N_c = 2$	$N_c = 1$
1	495	795	.72	.54	.64	.55
2	700	664	.51	.25	.58	.46
3	573	360	.73	.37	.63	.53
4	1000	634	.38	.20	.53	.34

Notes

[1] Based on the proportion of vehicles not found in platoons with an average headway of less than the value shown. For example, for Group 1, 72% of the vehicles were not in platoons with an average headway of 2 seconds or less.

[2] N_c: Number of circulating lanes (1 or 2)

Other, qualitative observations, critical in understanding the capacity characteristics of the traffic circle, are worth noting. First, even though the entryways are two lanes wide, nearly all (at least 90 percent) of the entering traffic uses the far right-hand lane. Second, despite the fact that the traffic circle is two lanes wide, vehicles tend to follow single file around the circulating roadway. No more than 1 car in every 20 occupies the inside lane alongside another vehicle. This is not to say that the inside lane goes unused, but that drivers treat it as a passing lane, to be used to advance one's own vehicle around another that is exiting when the probability of being cut off from one's own exit objective is small. Third, vehicles on the entryways tend to take into account all of the circulating flow, not just that in the outside lane, when checking for gaps to accept. Finally, the extent to which both lanes are used, either in the traffic circle or on the entryways, is very limited, a finding that is in keeping with experience abroad (*1,6*).

Before turning to the capacity analysis, two final notes seem appropriate. First, the data in Table 3 for the southbound approach (Group 3) should probably be omitted when estimating default values for t_a and t_f for other locations; that junction rarely operates at capacity. If this is done, the bounds on t_a tighten to 2.9 to 3.7 sec, and on t_f, 1.7 to 2.2 sec. The other note is that these values are for all vehicles on a given approach, and since the approaches are all nominally two lanes wide, a lane-by-lane analysis would most likely generate larger values.

TABLE 3 Minimum Acceptable Gap t_a and Follow-Up Gap t_f

Group	t_a	t_f	R^2	Total Absolute Difference[1]	Maximum Absolute Difference[2]
Based on Siegloch (22)					
1	3.45	1.81	.912	15	2
2	3.65	1.79	.891	7	1
3	4.06	3.29	.998	4	1
4	2.93	2.05	.919	39	2
Based on Armitage and McDonald (3)					
1	2.89	2.18	n/a	72	6
2	3.60	1.71	n/a	54	3
3	3.87	3.68	n/a	28	2
4	3.41	1.84	n/a	247	7

[1] Σ |projected number that could use gap - vehicles using gap|
[2] Maximum (|projected number that could use gap - vehicles using gap|)

CAPACITY ANALYSIS

To conduct the capacity analysis, the data plotted in Figure 3 were compared and contrasted with the predictions of various capacity equations developed abroad. By using the gap parameters described earlier, it was hoped that one or more of these equations might produce reasonable upper bounds for the throughput values depicted in the figure.

Eight equations were examined: three developed for prioritized junctions in general—Siegloch (*21*), Harders (*22*), and Jacobs (*23*)—and five that have been used in traffic circle situations—Troutbeck (*6*), Bennett (*20*), Stuwe (*24*), Brilon and Stuwe (*1*), and Kimber (*16*).

Of the first three, Harders' equation (*22*) is as follows:

$$C_e = Q_c \frac{e^{-q_c t_a}}{1 - e^{-q_c t_f}} \tag{1}$$

where

Q_c = flow rate of circulating stream (vph),
q_c = flow rate of circulating stream (vph/sec), and
C_e = capacity (maximum possible flow rate) for entering stream (vph) given Q_c,
t_a = critical gap for entering drivers (sec), and
t_f = follow-on time for entering drivers (sec).

Siegloch's equation (*21*) is as follows:

$$C_e = \frac{3{,}600}{t_f} e^{-q_c t_o} \tag{2}$$

where t_o is given by

$$t_o = t_a - \frac{t_f}{2} \tag{3}$$

Finally, Jacob's equation (*23*) is

$$C_e = \frac{\alpha Q_c e^{-\lambda(t_a - \tau)}}{\lambda t_f} \tag{4}$$

where α is the proportion of free vehicles in the circulating traffic stream and λ is defined as

$$\lambda = \frac{\alpha q_c}{1 - \tau q_c} \tag{5}$$

From the equations that have been applied to traffic circles, five were explored. The first is Troutbeck's (*6*):

$$C_e = \frac{\alpha Q_c e^{-\lambda(t_a - \tau)}}{1 - e^{-\lambda t_f}} \tag{6}$$

and the second is Bennett's (*20*):

$$C_e = \frac{\alpha Q_c e^{-\lambda(t_a - \tau)}}{1 - e^{-q_c t_f}} \tag{7}$$

The third is the regression equation developed by Stuwe (*24,1*):

$$C_e = Ae^{-BQ_c/10{,}000} \tag{8}$$

where $A = 1{,}577$ and $B = 6.61$ on the basis of observations at 4,574 traffic circles with two entry lanes and two circulating lanes in Germany. The fourth model is an alternative regression equation developed by Brilon et al. (*25*):

$$C_e = Ae^{-BQ_c/10{,}000} + DN_c + EN_e \tag{9}$$

where

$A = 1{,}549$,
$B = 8.4$,
$D = 208.4$, and
$E = 48.02$.

The fifth and final model in this group is Kimber's (*16*), which predicts traffic circle capacity on the basis of geometric parameters:

$$C_e = K(F - f_c Q_c) \tag{10}$$

where

$$K = 1 - 0.00347(\Psi - 30) - 0.978(\frac{1}{r} - 0.05) \tag{11}$$

$$F = 303x_2 \tag{12}$$

$$f_c = 0.21t_d(1 + 0.2x_2) \tag{13}$$

$$t_d = 1 + \frac{0.5}{1 + e^{\frac{D-60}{10}}} \tag{14}$$

$$x_2 = v + \frac{e - v}{1 + 2s} \tag{15}$$

and

$$s = \frac{e - v}{l} \tag{16}$$

where

e = entry width (m),
v = approach half-width (m), and
l = average effective length over which flare is developed (m).

These parameters are also defined in Figure 5; D and r must be in meters, and Ψ must be in degrees. (Note that the e used in Equations 15 and 16 is a parameter whereas the e used in Equation 14 is the natural logarithm base.) For Latham Circle, the values that pertain are $\Psi = 35$ degrees, $D = 82.9$ m, $v = 7.32$ m, $r = 18.59$ m, $e = 8.36$ m, and $l = 15.68$ m. This yields constants of $K = 0.9789$, $t_d = 1.046$, $s = 0.0663$, $x_2 = 8.238$, $f_c = 0.5816$, and $F_c = 2496.2$.

Figure 6 shows a plot of the first three models (Harder, Siegloch, and Jacob) against the throughput values for the northbound approach, the busiest of the three (Group 4). (The values used for α, τ, t_a, and t_f are from Tables 1 through 3. For α, the 10th-percentile values were used; for τ, the 2-sec values; and for t_a and t_f, the Armitage- and McDonald-based values.) Although these models might provide plausible upper bounds for the junction's potential throughput, since the observations displayed are all 1-min values, it is not likely that the values purported by the models can be achieved on a sustained basis. One must remember that these equations should reflect the sustained 1-hr capacity of the facility, not its 1-hr capacity. Hence, equations that predict the true 1-hr capacity should lie in the upper reaches of but not above the 1-min throughput values observed. [Hakkert et al. discuss this point (*8*).]

Figure 7 shows the capacity relationships estimated by four of the traffic circle–based capacity models. Whereas Bennett's model

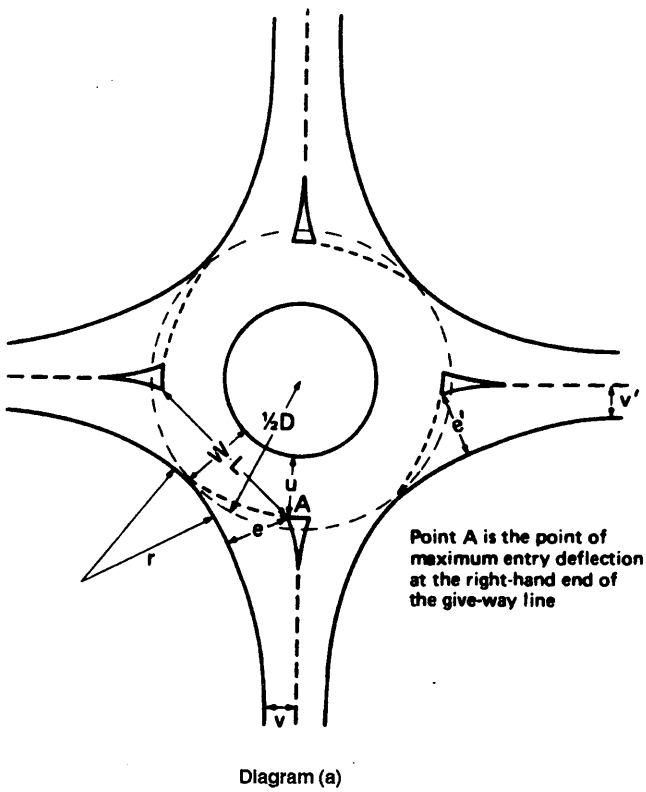
(i) The *entry width*, e, is measured from the point A along the normal to the nearside kerb, see Diagram (a).

(ii) The *approach half-width*, v, is measured at a point in the approach upstream from any entry flare, from the median line to the nearside kerb, along a normal, see Diagram (a).

(iii) The *entry width*, e', and *approach half-width*, v', for the *previous entry* are measured in the same way as e and v, see Diagram (a).

(iv) The *circulation width*, u, is measured as the shortest distance between point A and the central island, see Diagram (a).

(v) Two alternative constructions can be used to obtain the *average effective length over which the flare is developed.* The first (ℓ) is as used previously (see reference 3), and is shown in Diagram (b).



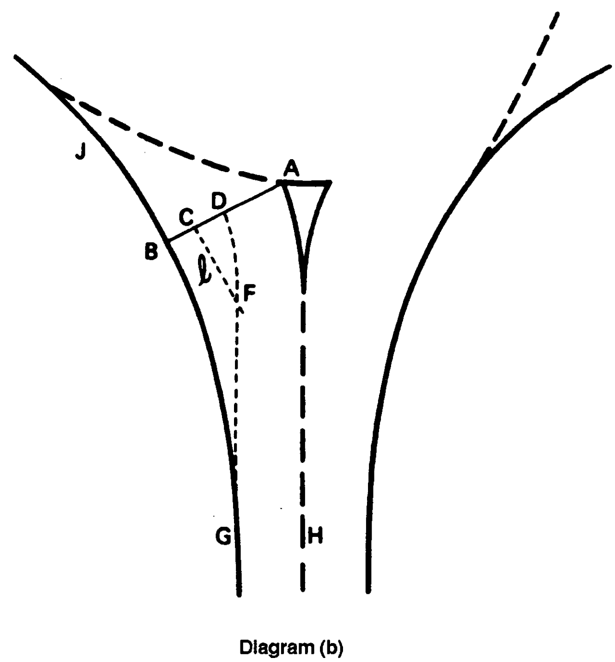


FIGURE 5 Kimber's model and parameter definitions.

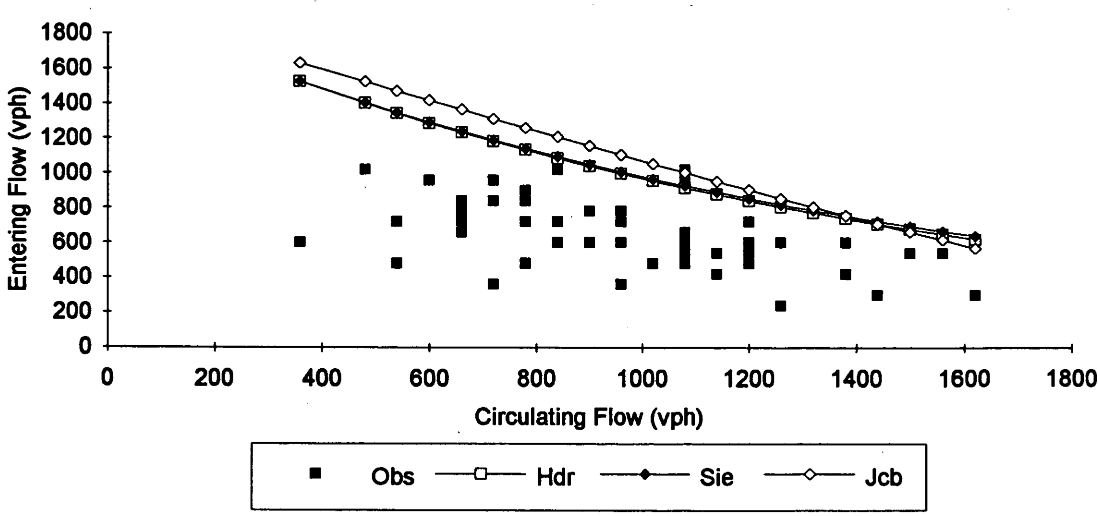


FIGURE 6 Three priority junction models: Group 4, northbound approach.

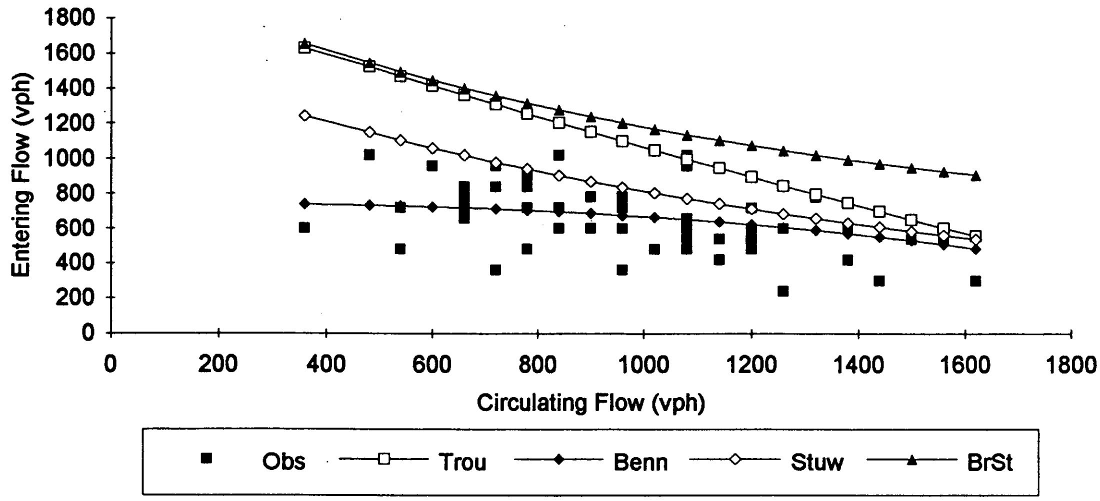


FIGURE 7 **Four traffic circle models: Group 4, northbound approach.**

appears to underestimate the potential maximum throughput, the models of Troutbeck and of Brilon and Stuwe probably overestimate it. Stuwe's model appears the most likely to provide reasonable values for this particular site given the input parameters employed.

Looking at all of the approaches simultaneously, Figure 8 provides a plot of the predictions of Troutbeck's model for all four data groups. One can see the effects of changes in the parameter values for the capacity predictions. In contrast, if the predictions of Stuwe's model were displayed, there would be no differences in capacity prediction since that model depends on only one parameter: the circulating volume.

Kimber's model (*15*) generates capacity estimates significantly in excess of the throughput values observed. This suggests that the familiarity of British motorists with traffic circles dramatically increases the achievable throughput.

Table 4 gives the predicted values of C_e for each of the eight models for Data Groups 1 through 4. It is clear that all of the models estimate Q_e values higher than those observed. But that is to be expected since, as noted earlier, none of these approaches, except the northbound one (Groups 2 and 4), appeared to be at or near capacity in the field.

ACCIDENT TRENDS

An examination of the accident trends of Latham Circle is important because traffic circles are generally considered by U.S. motorists to be hazardous locations. At Latham Circle, between 1989 and 1991 there were 169 accidents, broken down as given in Table 5. None of the accidents involved fatalities, 37 involved injuries, 54 had property damage only, and the remaining 88 had consequences lower than $600, the minimum reportable threshold. Given the AADTs for US-9 (22,900 south of the traffic circle and 19,380 north) and NY-2 (20,960 west of the traffic circle and 17,900 east), the average annual daily number of vehicles entering the traf-

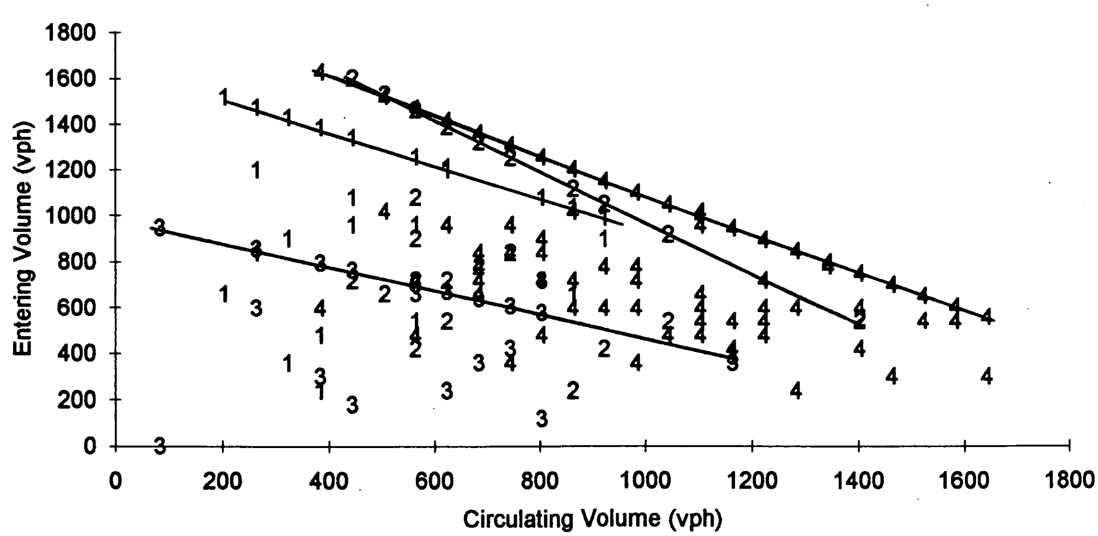


FIGURE 8 **Troutbeck model for all four groups.**

TABLE 4 Comparison of Capacity Predictions

Group	Observed		Predicted Maximum Entryway Volume							
	Q_c	C_e	Harder	Sieg-loch	Jacob	Trout-beck	Bennett	Stuwe	Brilon-Stuwe	Kimber
1	495	795	1284	1289	1292	1288	1117	1137	1535	2162
2	700	664	1229	1235	1280	1277	934	993	1373	2045
3	573	360	698	708	694	685	651	1080	1470	2117
4	1000	634	969	979	1070	1067	669	814	1181	1874

fic circle is approximately 40,570. This implies an accident rate of 3.8 accidents per million vehicles entering. Although this value exceeds the statewide overall average of 0.88 accidents per million vehicles entering, it is within the range of values reported by Brilon et al. (*25*) for German conditions: 6.58 for medium and large traffic circles, 1.24 for smaller traffic circles, 3.35 for junctions with traffic signals, and 1.00 for junctions without traffic signals.

Consideration of the accidents by type shows that none was fatal and only 21.9 percent involved injuries. By comparison, statewide, 0.2 percent of all accidents are fatal and 37.6 percent involve injuries. The difference from the statewide average in the percentage of fatal accidents may not be significant, but the injurious accident percentage difference might be. Many researchers abroad have found that modern traffic circles tend to produce significantly fewer injury accidents than the average intersection (*4,15,17,25–28*).

Of the accidents, 24 percent were rear-end collisions, predominantly on the ramps, and 11 percent were right-angle collisions, half on the traffic circle and half on the ramps. Nine percent were overtakes and the rest were sideswipes (3 percent), collisions with fixed objects, especially guardrails and curbs (2 percent), and nonreportable accidents (51 percent) for which no event description is provided.

DISCUSSION OF RESULTS

Unfortunately, nowhere in the preceding analysis does the subject of level of service appear. No one abroad has explicitly considered the kind of delay-based performance assessment that has become so much a part of U.S. capacity analyses (*29*). It is uncommon to find a paper, such as that by Troutbeck (*6*), in which the relationship between average delay per vehicle and degree of saturation is addressed. It is important to know how average delay varies with volume-capacity ratios—for example, to understand where traffic circles might be applicable, one should know, among other features, where delay performance is the best among all control devices available.

Other attributes are also important. One should know where the breakpoint is between these facilities and others, such as signalized and unsignalized intersections. One should also learn the characteristics of the delay curves of a traffic circle. Certainly, the capacity equations discussed earlier imply that the delay per vehicle at any given value of entering volume increases as the circulating volume increases. Logic suggests that this is probably true, but there are no empirical data to support this conclusion.

SUMMARY AND CONCLUSIONS

This paper has presented a capacity analysis of Latham Circle, located in Latham, New York, outside of Albany. From videotapes, 1-min observations of entry flow were correlated with simultaneous observations of circulating flow. Values for the average minimum acceptable gap, minimum circulating headway, move-up time, and geometric parameters were calculated so that various capacity equations, established abroad, could be compared and contrasted with the circle's performance. Prioritized junction capacity equations proposed by Harders (*22*), Siegloch (*21*), and Jacob (see *23*) and traffic circle capacity equations proposed by Bennett (*20*), Troutbeck (*6*), Stuwe (*24*), and Brilon et al. (*25*) were all found to provide plausible upper bounds on the circle's observed throughput. Moreover, all but the last of these appear to provide capacity esti-

TABLE 5 Accident Statistics for Latham Circle

	Accidents by Category					
Year	FTL	INJ	PDO	N/R	TOT	AR
1989	0	9	18	47	74	5.00
1990	0	15	19	23	57	3.85
1991	0	9	12	17	38	2.57
TOTAL	0	33	49	87	169	3.80

Facility......................AADT

SR-9 North of Circle........19,380
SR-9 South of Circle........22,900
SR-2 West of Circle.........20,960
SR-2 East of Circle.........17,900

Key

FTL: Fatal Accident
INJ: Injurious Accident
PDO: Property Damage Only Accident
N/R: Non-reportable accident (<$600 damage)
TOT: Total accidents
AADT: Average Annual Daily Traffic
SR-9: State Route 9
SR-2: State Route 2

mates that match quite closely the greatest of the throughput values observed. Therefore, it appears plausible that one or more of these capacity relationships may be adaptable to U.S. conditions without significant recalibration.

The capacity models developed for British and Australian conditions, however, appear to overestimate the maximum throughput levels achievable. This indicates either that maximum throughput conditions were not observed, which seems unlikely, or that the experience of British and Australian drivers with traffic circles allows them to achieve higher throughput values than those currently possible here, at least for this particular circle. Hence, these equations might have to be recalibrated before being used in the United States.

Finally, a close correspondence was found between the observed gap parameters and those found to be typical abroad for these equations—for example, values for t_a, t_m, and t_f suggested by Bennett (*20*), Austroads (*18*), and Armitage and McDonald (*19*). This lends further evidence to the fact that similarities in driver behavior may exist.

The conclusion drawn from this analysis is that it appears possible to transfer capacity equations from abroad to the United States. Not only are calibration constants similar in some instances, but maximum levels of throughput also seem to correspond with the capacity predictions of models developed abroad.

It is important to note, however, that the study of traffic circles abroad has not included a focus on their delay characteristics, especially the way in which delay varies with volume-capacity ratios. The perspective of level of service has not been employed.

Hence, the major task ahead appears to be one of developing capacity relationships for domestic conditions that build on the equations already developed overseas. In fact, such an initiative should be seen as an opportunity to increase the international commonality in the treatment of capacity and level-of-service issues pertaining to such facilities.

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