TECHNICAL NOTE

CALIBRATION OF TWO-LANE ROUNDABOUT MODELS IN VOYAGER AND PARAMICS

Author and Presenter:

Alistair Smith, Ph.D., MIPENZ (Transportation Group)
Senior Transportation Modeller, Traffic Design Group Ltd
alistair.smith@tdg.co.nz

ABSTRACT:

The Gap Acceptance algorithm for modelling roundabouts in CUBE VOYAGER transport modelling software is only calibrated for single-lane roundabouts. We have performed tests using PARAMICS and VOYAGER of conflicted flow through a two-lane roundabout, in order to calibrate the VOYAGER model for application to two-lane roundabouts. The calibration was achieved by varying the VOYAGER parameters (outside the recommended range) until the VOYAGER delays matched the PARAMICS delays. The Empirical algorithm in VOYAGER was also tested. The results from the analysis produced recommended parameters (as well as the recommended algorithm) for modelling two-lane roundabouts in VOYAGER.

The methodology developed and followed for this calibration exercise incorporated additional comparisons and analysis, such as the sensitivity of the delay to the model parameters, the turning movement capacities, and the base-case PARAMICS model used for calculating PARAMICS delays.

INTRODUCTION

CUBE VOYAGER[1] is a software package used for building strategic (*macro*-simulation) models. As individual vehicles are not represented in VOYAGER traffic assignment modelling; algorithms and equations are used to estimate turning delays from conflicting flow volumes for various intersection types. Broad consistency in delay results between CUBE VOYAGER and *micro*-simulation models, which incorporate vehicle-level dynamics, is highly desirable.

A calibration exercise has been undertaken to determine the preferred algorithm in VOYAGER for modelling roundabouts, focusing particularly on multilane roundabouts. In this case PARAMICS[2] has been selected as the modelling software to serve as the benchmark for calibration: it is a well-recognised and commonly used microsimulation tool.

The options currently available in VOYAGER for modelling roundabouts are the 'Gap Acceptance' and the 'Empirical' algorithms. The Gap Acceptance algorithm is based on the US Highway Capacity Manual (HCM), and involves specifying the 'Critical Gap' and 'Follow-up Time', in seconds, for each approach of the roundabout. The Empirical algorithm is from UK research on the effective capacity of turning volumes; it involves specifying the 'Capacity Intercept' (capacity given no conflicting flow) and the 'Capacity Slope' (decrease in capacity with each conflicting vehicle). The Gap Acceptance algorithm is presently only calibrated for single lane roundabouts, with a recommended parameter value range provided. This algorithm can be applied to multilane roundabouts using parameter values outside of the recommended HCM range and appears to respond adequately. Tests in congested conditions, however, indicate that the capacity at multilane roundabouts may be under-estimated and hence this review exercise was instigated.

This technical note documents the calibration methodology for modelling multilane roundabouts in VOYAGER, presents the results of the analysis, and reports recommendations for the algorithm and parameters to be applied.

CALIBRATION

A four-arm two-lane roundabout, with arbitrary traffic volumes on each approach, was modelled with both PARAMICS and VOYAGER. The average vehicle delays on each approach from the PARAMICS model were used as target delay values for the calibration and assessment of the VOYAGER algorithms. Two volume scenarios were modelled, namely Scenario A and B, both consisting of four through-movements, Scenario B having increased approach volume on the fourth arm.

PARAMICS Model

The roundabout geometry in the PARAMICS model is shown in Figure 1. All road links were two-lanes, 7.3m wide, 50kph speed limit, and operated with generic driver behaviour. The inside and outside diameters of the roundabout were approximately 45m and 60m respectively.

[1] See www.citilabs.com/cube_voyager.html for more information on CUBE VOYAGER

[2] See www.sias.com/ng/spoverview/spintroduction.htm for more information on PARAMICS

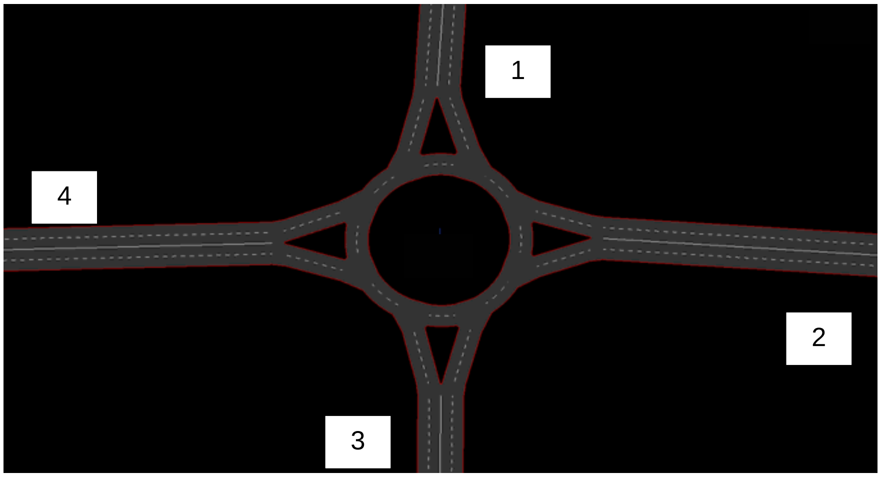

Figure 1: Multilane Roundabout in PARAMICS

The model was run for an initial five-minute warm-up period, then for 60 minutes in which average vehicle travel times were extracted for each approach. In order to decompose these travel times into link time and intersection delay, a model with base case geometry was also constructed. The base case was constructed from the roundabout geometry, with: the approach and exit links deleted; the roundabout links (and nodes) deleted; a straight link connecting approach 1 to approach 3; and a straight link connecting approach 2 to approach 4. The two new links in the base case passed each other without conflict, that is, without any connecting node. The intersection delay at the roundabout was therefore the travel time with the roundabout case less the travel time in the base case.

As simulation is stochastic in nature, the simulation of traffic through the roundabout was run five times for each scenario, and the travel time per vehicle was taken as an average over these runs. Only one run was required for the base case, as travel times were consistent across scenarios and also had very low standard deviations within the first run (<0.001).

VOYAGER Model

The network configuration constructed for the VOYAGER model was the same to that in PARAMICS, except lacking the roundabout geometry; the intersection consisted of a single node, to which each of the four zones were connected by a two-way link.

Using the Gap Acceptance (HCM) method, the parameters required in VOYAGER are the Critical Gap and the Follow-up Time. In the Empirical Method, the user can input geometric parameters (Entry Width, Approach Width, Flare Length, Inscribed Diameter, Entry Radius and Entry Angle) from which the VOYAGER software calculates the Capacity Slope and Capacity Intercept; alternatively the Capacity Slope and the Capacity Intercept can be entered directly. In order to reduce the number of variables for this exercise, the Capacity Slope and Capacity Intercept were entered. Both algorithms are therefore determined by two input parameters.

For each scenario and algorithm, the input parameters in the VOYAGER model were varied until the resultant intersection delays by approach most closely matched the delays from the PARAMICS model, using a combination of the sum of absolute differences and the flow-weighted average delay. Parameters were restricted to one decimal place for Critical Gap, Follow-up Time and Capacity Slope, while Capacity Intercept was restricted to multiples of 100.

Results

Two volume scenarios were modelled, A and B, both consisting of four through-movements. In Scenario A, the optimum parameters using the Gap Acceptance algorithm are Critical Gap of 4.2s and Follow-up Time of 1.4s. Using the Empirical algorithm, the optimum parameters are Capacity Slope of 1.1 and Capacity Intercept of 2100. Based on these input parameter values, the delays calculated by VOYAGER are shown in the following table compared with the results from the microsimulation model.

Table 1: Scenario A Results Based on Optimal Parameters

Approach	Volume (Through Movement)	PARAMICS Delay	VOYAGER DELAY	
			Gap Acceptance	Empirical
1	1200	0.24	0.20	0.21
2	500	0.27	0.26	0.29
3	1200	0.19	0.20	0.21
4	500	0.24	0.26	0.29
Sum of Absolute Differences			0.07	0.12
Flow-Weighted Average		0.23	0.22	0.23

In Scenario B, the optimum parameters using the Gap Acceptance algorithm are Critical Gap of 4.6s and Follow-up Time of 1.2s. Using the Empirical algorithm, the optimum parameters are Capacity Slope of 1.1 and Capacity Intercept of 2100 (same as in Scenario A). Again, these parameter values were input to VOYAGER, and the delays calculated for Scenario B traffic volumes are shown in the following table compared with the results from the microsimulation model.

Table 2: Scenario B Results Based on Optimal Parameters

Approach	Volume (Through Movement)	PARAMICS Delay	VOYAGER DELAY	
			Gap Acceptance	Empirical
1	1200	0.54	1.37	1.51
2	500	0.27	0.27	0.29
3	1200	0.18	0.14	0.21
4	800 (was 500 in Scenario A)	3.59	2.87	3.41
Sum of Absolute Differences			1.60	1.20
Flow-Weighted Average		1.03	1.13	1.32

These results show that both algorithms were capable of broadly reproducing the PARAMICS delays. Scenario B, which had higher traffic volumes on one arm, performed slightly worse while Scenario A is replicated well. For the Gap Acceptance method, Scenario A and B resulted in slightly different parameter values. Mid-point parameters, with the Critical Gap set to 4.4s and the Follow-up Time to 1.3s, were adopted as the preferred Gap Acceptance Model.

SENSITIVITY OF DELAY TO PARAMETERS

To assess the sensitivity of the delay to the input parameters, the percentage changes in total intersection delays were normalised by the percentage changes in the input parameters (at the preferred parameters) to give effective elasticity values. Results are shown in Table 3.

Table 3: Elasticities

VOYAGER Model		**ELASTICITY**	
		Scenario A	**Scenario B**
Gap Acceptance	Critical Gap	4.0	12.0
	Follow-up Time	3.1	7.6
Empirical	Capacity Slope	6.2	12.1
	Capacity Intercept	-10.3	-20.9

Elasticity results show that the intersection delays are much more sensitive to the input parameters using the Empirical algorithm, meaning that a wider range of results is obtainable using this method, but the results are less stable.

EVALUATION OF PERFORMANCE FOR AN UNOPPOSED FLOW

An unopposed flow through a roundabout, that is, a flow on a single approach with no other traffic using the roundabout, was also tested with PARAMICS and VOYAGER. This provides a strong assessment of the model's ability to replicate capacity, and hence delay. The PARAMICS capacity was determined by increasing the demand until the delays increased dramatically.

An approach volume of 2000 vehicles was then tested in VOYAGER using: the preferred Gap Acceptance model; the Empirical model with the capacity selected to match that of PARAMICS; and the Empirical model with the previously calculated capacity. Results are shown in Table 5.

Table 4: Unopposed-Flow Results

Table 5: Unopposed-Flow Results	**Capacity**	**Delay**
Two-Lane; Approach Volume = 2000		
PARAMICS	2708	0.18
VOYAGER		
Gap Acceptance (Critical Gap=4.4, Follow-Up Time=1.3)	2766	0.08
Empirical (Capacity Intercept =2708) (Selected to match PARAMICS)	2708	0.08
Empirical (Calibrated Capacity Intercept=2100) (Optimal from previous analysis)	2100	0.46

CONCLUSIONS

The same volume scenarios were modelled with PARAMICS and VOYAGER for a two-lane roundabout in order to identify the preferred VOYAGER intersection algorithm and to calibrate the relevant parameters.

The two algorithms in VOYAGER could approximately reproduce the PARAMICS average vehicle delays by approach for typical volumes on a two-lane roundabout, and were sufficiently responsive to changes in approach volumes. However, intersection delays were more sensitive to input parameters using the Empirical algorithm, and conversely more stable using the Gap Acceptance algorithm.

Based on these results, the preferred model for a two-lane roundabout is the Gap Acceptance (HCM) algorithm. The calculated parameter values are Critical Gap of 4.4s and Follow-up Time of 1.3s for a two-lane roundabout.

PARAMICS tests also indicate that the capacity intercept for two-lane roundabouts is 2708 per approach. The capacities and delay for this scenario was satisfactorily reproduced using the calibrated VOYAGER Gap Acceptance model, performing better than the Empirical model.