Modelling Two-Lane Roundabouts: CUBE VOYAGER vs S-PARAMICS

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Introduction

CUBE VOYAGER is a software package used for building strategic 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 S-PARAMICS 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 aim of this particular exercise is to identify the VOYAGER model that best replicates PARAMICS delays for a test case two-lane roundabout.

Roundabouts in VOYAGER

The options (algorithms) currently available in VOYAGER for modelling roundabouts are:

- Gap Acceptance; and
- Empirical.

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.

Test Case

A four-arm two-lane roundabout, with test traffic volumes on each approach, was modelled with both PARAMICS and VOYAGER.

Paramics Model

The roundabout geometry in the PARAMICS model is shown in Figure 1. All road links were two-lanes (in each direction), 3.65m lane width, 50kph speed limit, and operated with generic driver behaviour. The inside and outside diameters of the roundabout were approximately 45m and 60m respectively.

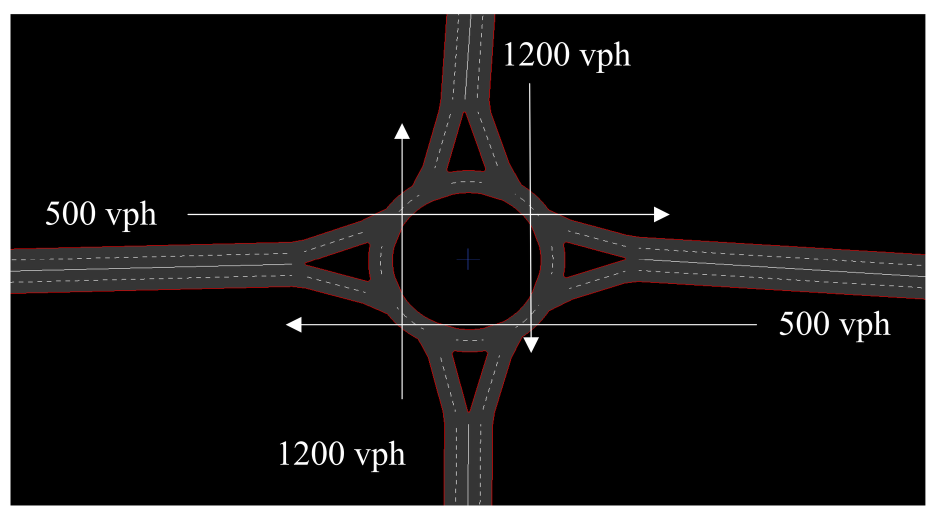

Figure 1: Paramics Roundabout

The PARAMICS 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.

A base network was constructed, without any roundabout geometry or any flow conflicts (ie flyover). This base network therefore simulated link dynamics only, so that the roundabout intersection delay could be calculated as the travel time in 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 as 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, as shown in Figure 2.

NB It is this simplicity of network coding that allows CUBE VOYAGER models to be constructed quickly and easily for large areas and/or for comprehensive option tests.

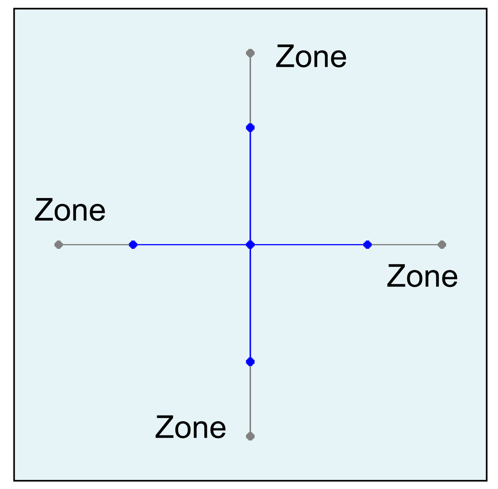

Figure 2: Voyager Roundabout

Delay

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. For each 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 the sum of absolute differences as well as the flow-weighted average delay. Delay results (in minutes) are shown in Table 1.

Approach	Volume (vph)	PARAMICS Delay (min)	VOYAGER DELAY (min)	
			Gap Acceptance	Empirical
North	1200	0.24	0.20	0.21
East	500	0.27	0.26	0.29
South	1200	0.19	0.20	0.21
West	500	0.24	0.26	0.29
Sum of Absolute Differences			0.08	0.12
Flow-Weighted Average		0.23	0.23	0.23

Table 1: Delay Results

The results shown in Table 1 were obtained with the following optimised parameters.

- Gap Acceptance: Critical Gap = 4.4s; Followup Time = 1.3s
- Empirical: Capacity Intercept = 2100; Capacity Slope = 1.1

Capacity

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 queues and delays began to increase markedly.

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 2.

	Capacity (vph)	Delay (min)
Two-Lanes; Approach Volume = 2000		
PARAMICS	2708	0.18
VOYAGER Gap Acceptance (Critical Gap=4.4, Follow-Up Time=1.3)	2766	0.08
VOYAGER Empirical (Capacity Intercept =2708) (Selected to match PARAMICS)	2708	0.08
VOYAGER Empirical (Calibrated Capacity Intercept=2100) (Optimal from previous analysis)	2100	0.46

Table 2: Capacity Results

Results shown in Table 2 indicate that the Gap Acceptance algorithm compares well with PARAMICS capacity, but underestimates delay, for this non-conflicted scenario. The Empirical algorithm, using the PARAMICS capacity, also underestimates delay. With the previously optimised capacity parameter, the Empirical algorithm overestimates delay.

Summary

- 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 broadly reproduce the PARAMICS average vehicle delays by approach for test volumes on a two-lane roundabout. However, intersection delays were more sensitive to input parameters using the Empirical algorithm, and conversely more stable using the Gap Acceptance algorithm.
- PARAMICS tests indicate that the capacity intercept for two-lane roundabouts is approximately 2700 per approach. The capacity and delay for this non-conflicted scenario was satisfactorily reproduced using the calibrated VOYAGER Gap Acceptance model, performing better than the optimised Empirical model.
- Based on these tests, the preferred model for modelling two-lane roundabouts in VOYAGER is the Gap Acceptance (HCM) algorithm, with Critical Gap of 4.4s (similar as for one-lane roundabout) and Follow-up Time of 1.3s. (usually 2.5s to 3.0s for one-lane roundabout).

About the Author

ALISTAIR SMITH

- Qualifications: B.Sc. (1st Class Hons), University of Canterbury, 2000;
  Ph.D. Computational and Applied Mathematics, University of Canterbury, 2003.
- Alistair's areas of expertise are strategic transportation modelling, data analysis, computation, economic assessment and research.
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