ROUNDABOUT CALIBRATION IN CHILE USING aaSIDRA: A CYCLING QUEUE REPLICATION PROCESS

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ABSTRACT

In this paper is shown the study of aaSIDRA program and the calibration method designed for its efficient use on roundabouts simulation in Chile.
In order to accurately calibrate the program an analysis of driver behavior is required. This process is simulated by choosing the program parameters that describe the intersection approach. The specific parameters to be analyzed in this research are those associated to critical gap and the follow-up headway on queues. These parameter values are based on direct field observation and are used as a starting point for an iterative calibration process: the initial values for the critical gaps are derived using a maximum likelihood technique while the initial values for the follow-up headways are measured directly from field observations.
The result of this research is twofold: it is an empirical demonstration for the need of a calibration process an secondly it is also presented as an approach to calibrate roundabouts based on a cycling queue replication process not reported yet in the literature.

Keywords: aaSIDRA, calibration, roundabout.

RESUMEN

En este trabajo se presenta el estudio del programa aaSIDRA y el método de calibración diseñado para su uso eficiente en Chile.
Un análisis preciso del comportamiento de los conductores fue indispensable para este proceso, el cual se concentra en aquellos parámetros que mejor describen e influyen en la modelación de la intersección en estudio. Los parámetros más significativos fueron la brecha crítica y el intervalo de seguimiento en las colas de espera. Estos parámetros están basados en observaciones directas de terreno y son usados como punto de partida para el inicio del proceso iterativo de la calibración.: los valores para la brecha crítica se derivaron a través de una técnica de máxima verosimilitud, mientras que los valores iniciales de los intervalos de seguimiento se midieron directamente en terreno.
El resultado de esta investigación es doble: demuestra la necesidad imperiosa de la calibración, y así mismo se presenta una heurística para calibrar basada en un proceso de replicación de colas cíclico no reportado en la literatura.

Keywords: aaSIDRA, calibration, roundabout.

1. INTRODUCTION

Priority intersections constitute the majority of intersections in every country. In Chile, many of these are not properly modeled and in resent years the unjustified implementation of traffic lights in priority junctions has grow up strongly. Most of these cases are the result of choosing the intersection design without any analysis. Roundabouts in Chile have a background of bad design and therefore they are constantly criticized by different social actors.
The objectives of this paper are to give an empirical demonstration for the need of a calibration process giving the error magnitude when such process is not taken into account, and secondly to design an approach to calibrate roundabouts based on a cycling queue replication process.

2. BACKGROUND LITERATURE

2.1. Preliminary Definitions

A roundabout has at least three arms, generally with one or more entrance lanes and one or more exit lanes. Nonetheless certain designs allows for arms to be implemented as only exit or only entrances. Drivers that are waiting to enter the roundabout are known as the entering flow or non priority flow while the circulating vehicles can be identified as the priority flow. If we consider lane behavior a different denomination is used: The circulating lane which has the smallest perimeter is the far major lane while the one with the greater perimeter is known as the near major lane. If there are two lanes on an access these are named as inner minor lane and outer minor lane.

According to Polus (1983) a gap is the time interval between two consecutive vehicles on the main flow. In relation to this, Hewitt (1985) defines a critical gap as the minimum gap between two vehicles of the priority road that a vehicle of the minor road needs in order to cross the road or enter into the flow. This definition is somehow a little unrealistic because it considers that the driver will react the same way to two gaps of the same length. Even more it is impossible to predict exactly the speed of vehicles and the distance between them. Drew (1968) proposes a different definition in which a critical gap is considered as the one that similar drivers will reject if compared to a smaller one and will accept if compared to a larger one. More specifically Greendshields (1947) defines it as the one that is accepted for the half of the drivers. Troutbeck (2001) simplified the definition saying that the critical gap is the one that driver considers acceptable. Further more Troutbeck (2001) exposes that even though direct measure of the critical gap is impossible, the following relationship can be stated:

$$\textbf{largest gap rejected} \; < \; \textbf{critical gap} \; \leq \; \textbf{gap accepted} \qquad (2.1)$$

As the gap acceptance model is based on the driver's behavior, it is assumed that the critical gap may vary form driver to driver. This implies that if we even consider the very same driver, the critical gap may also vary. This imposes strong difficulties for any kind of study. For these reasons it is necessary to state the following definitions:

- A driver has a **consistent** behavior if he always has the same critical gap.

- If the drivers chooses critical gaps of the same distribution, common to all drivers, it can be said that the drivers are **homogeneous**.

In order to complete the basic terminology for the study of priority intersections we also have to include the definitions for lag and headway. Plank (1982) says that a lag is the time between the moment that a vehicle arrives to the stop lane and the time that the first vehicle of the main flow passes in front of it. Accordingly the same author defines headway as the time interval between two consecutive vehicles that cross the same point on the road. Following up Weinert (2000) defines the follow-up headway as the headway between two consecutive vehicles that succeed in crossing or entering the major flow on the moment that they cross the stop lane. Other authors refer to this term as follow-up time or follow-on headway.

2.2. Performance index

Delays and queues are the most used performance index in the majority of published studies related to priority intersections. Besides these, capacities are useful in order to compare different intersections. Tanner (1962) established that the capacity of a priority intersection is reached when the minor road is saturated or present queues grow to infinity. In a similar way Kimber (1976) defined that the capacity of a roundabout is reached when present continues queues. The use of capacity as a tool to compare roundabouts is quite popular. According to Drew (1968) the capacity is defined as the maximum number of vehicles that can go through a point on the road during a period of time under certain traffic conditions. There is not an exact definition for the capacity of a roundabout. Hagring (1998) said that the capacity of the roundabout is reached when the capacity of the most saturated entrance is reached.

The use of queues as a tool for measuring performance is very common: it is undoubtedly the easiest method to measure in field experiences. But queues are of different types: there are maximum queues, average queues, and sometimes only light vehicles will be accounted.

Regarding the use of delays as a performance index it can be said that it has several issues. For example, apart from the operational delay there is the geometric delay that depends on the intersection shape.

2.3. Calibration and validation

In a research of this nature it is essential to define the differences between calibration, validation and verification. For Law & Kelton (1991) calibration is the process in which the parameters of a model are modified to adjust modeled results with those observed. This definition is the one that will be assumed in this paper.

The definition of validation on the other side is taken from Lieberman & Rathi (1997) that defines it as the process that establishes if the behavior of the model represents the real system. Using input data from a completely different scenario but for the same intersection the validation allows to show if parameters that were adjusted for a base case work correctly in a different scenario

The simplest definition of verification of a model is given by Rakha et al. (1996) in which is the process in which is verified the mathematical models.

3. EXPERIMENTAL DESIGN

3.1. Choosing calibration parameters

For aaSIDRA programmers the calibration process consists mainly in the estimation of the critical gap and the follow-up headway from field observation and their usage as an input for the model. The beginning of the process is settled in the definition of a test roundabout to measure the sensibility of these parameters. This is almost the default roundabout of aaSIDRA but the origin destination flows have being chosen strategically to have saturated and non saturated accesses on the roundabout.

This process has four parts. In the first one the program is run with the test roundabout letting aaSIDRA estimate the values of the critical gap and follow-up headway for each of the 12 movements allowed at the intersection (3 possibilities for each one of the four accesses). The second step is to calculate the average value for the critical gap and for the follow-up headway and use that average as input data for all the accesses. Finally it is kept constant the value of the follow-up headway and the critical gaps vary (the same variation for all the movements of the intersections). The same thing is done varying the follow-up headway and keeping the critical gap on its average value.

Then it was studied the sensibility for the total average vehicles on queue, the maximum average queue and delays, keeping the second parameter on its average. It was found that if the critical gap increases from 3,7 to 4,7 seconds for all the accesses, the average total vehicles in queue almost triplicate from the former value of 45 to 130 vehicles while the average delay at the most saturated lane goes from 70 to 167 seconds.

Something similar occurs with the variation of the follow-up headway. With the increase of the average value from 2,3 to 3,3 seconds the total vehicles in queue goes from 45 to 161 and the average delay at the most saturated lane goes from 70 to 196 seconds.

Another interesting analysis is to verify that the ratio between the follow-up headway and the critical gap is close to 0,6 or 0,7. This fact is mention by the aaSIDRA authors.

3.2. Estimating the initial value for the critical gap

According to most authors (Troutbeck ,1992 and 2001; Kyte *et al,* 1996; Brilon 1999) the best method to estimate the critical gap for non priority movements at an intersection is the maximum likelihood method. This method consists basically in finding the mean and the standard deviation that best describes the sample.

To use this method it is necessary to previously specify a probability distribution for the gaps. The principal distributions used for this purpose are normal, log-normal, exponential and gamma.

Most authors (Drew *et al*, 1967; Troutbeck, 1992 and 2001; Hagring, 1998) however agree that the log-normal assumption offers the best fit to driver's behavior and has the advantage of having only positive values and a clear limit on the left. It is important to consider that for this case μ and σ are the mean and the standard deviation for $\ln(x)$.

There are three different methods that can be used for the estimation of the initial value of the critical gap. The first one and the simplest one is to consider that the circulation road has only one big lane and that the maximum likelihood method can be applied using a log-normal distribution function. The second method assumes two circulating lanes and no correlation between them. The third one also considers two circulating lanes but with a correlation structure between them. In this case it will be only used the first one.

The reason for this is based on field analysis and observations: it can be said that the Chilean driver has an erratic behavior on roundabouts. Even though the second and the third model are not presented in this paper the reader might see Leopold (2004) for a more complete analysis.

Considering:

- a_{xi} as the natural logarithm of the accepted gap by driver *i* crossing lane *x*.
- r_{xi} as the natural logarithm of the largest gap rejected by driver *i* crossing lane *x*.
- μ_x the mean of the distribution of the logarithms of the critical gaps.
- σ_x^2 the variance of the distribution of the logarithms of the critical gaps.
- $f(\cdot)$ the density function for a normal distribution.
- $F(\cdot)$ the cumulative function distribution for a normal distribution.

This notation is based in the fact that the use of a log-normal distribution can be treated like a normal distribution using the natural logarithms of the gaps as input variables. (See Tian *et al (*1999) and Troutbeck (2001) for more details). The likelihood of a sample of *n* drivers with an accepted gap and a largest rejected gap is:

$$\prod_{i=1}^{n}\left[F(a_{xi}) - F(r_{xi})\right] \tag{3.1}$$

Consequently the log-likelihood is simply:

$$L = \sum_{i=1}^{n}\ln\left[F(a_{xi}) - F(r_{xi})\right] \tag{3.2}$$

The maximum likelihood estimators of μ and σ^2 are given by the solution of this equation:

$$\frac{\partial L}{\partial \mu_x} = 0 \quad \text{and} \quad \frac{\partial L}{\partial \sigma_x^2} = 0 \tag{3.3}$$

An equivalent process is to solve through these two equations:

$$\sum_{i=1}^{n} \frac{f(r_{xi}) - f(a_{xi})}{F(a_{xi}) - F(r_{xi})} = 0 \quad \text{and} \quad \sum_{i=1}^{n} \frac{(r_{xi} - \mu_x) f(r_{xi}) - (a_{xi} - \mu_x) f(a_{xi})}{F(a_{xi}) - F(r_{xi})} = 0 \qquad (3.4)$$

Finally, having the mean and the variance for the sample and knowing the expression for the expected value and variance of a log-normal distribution it is possible to obtain the parameters of the original distribution defining that the critical gap and its variance are given by:

$$\left.\begin{aligned} g_{xc} &= \exp(\mu_x + 0{,}5\sigma_x^{\,2}) \\ \sigma_{x g_c}^{\,2} &= g_{xc}^{\,2}\left[\exp(\sigma_x^{\,2}) - 1\right] \end{aligned}\right\} \qquad (3.5)$$

3.3. Estimating the initial value for the follow-up headway

The procedure used to estimate the initial value of the follow-up headway is the one proposed by Troutbeck and Brilon (1997):

- Wait for large gaps at the major flow.
- Start a counter at the moment that the first vehicle passes the stop line entering a gap and watch the moment at which every vehicle using the same gap passes the stop line.
- Find the time differences.
- Do the same experiment for a larger number of gaps at the major flow and find an average.

3.4. Change data by lane to data by movement

The aaSIDRA model does all the intersection analysis based on a lane-by-lane model, (see Akçelik 1997) but the values for critical gaps and follow-up headways must be inputted by movements.

In sections 3.2 and 3.3 it was obtained initial values for the parameters of each lane entering the roundabout. The aaSIDRA model requires that data must be registered by movement. For example, if one access to the roundabout has two lanes, up to this point it means four values; critical gap and follow-up headway for each lane. aaSIDRA needs six values; critical gap and follow-up headway for vehicles that turn left, for vehicles that go theoretically through, and for vehicles that turn theoretically to the right.

It is possible to see three cases:

a) One lane access: This is the simplest case in which the values obtained for the critical gap and the follow-up headway for the single lane are the same used for the three movements.

b) Two lane access: The case is presented in the Figure 1.The same process is used for follow-up headways. For three or more access lanes it must be extended the same procedure. (See Leopold 2004)

3.5. Ratio between follow-up headway and critical gap

As stated before the ratio between the follow-up headway and the critical gap is almost constant and similar to 0,6 or 0,7.

This fact is an advantage in the calibration process because the calibrating parameters may be diminished to the half. As a consequence only critical gaps are calibrated because the values for the follow-up headways will be given by solving the follow-up headway from:

$$C^i{}_j = \frac{(f-u-h)^i{}_j}{(g_c)^i{}_j} \quad \text{with} \begin{cases} \forall i = Right, left, throw \\ \forall j = 1,\ldots,\mathrm{N}\ Access \end{cases} \qquad (3.6)$$

This constant is calculated for each movement after the estimation of the data by movements described in section 3.4.

3.6. Cycling queue replication process

This is the main part of the process and is based on changing the initial values for critical gap and follow-up headway until queues are replicated. To fulfill this process, the use of the maximum queues rather than average ones is preferred because they give better information.

The process is as follows:

1. Input data required to run the program: flows, geometric and control data, etc.
2. Input initial values of parameters by movement.
3. Compare queue lengths for each lane in each access.
4. For the access with the biggest differences, access *j*, increase or reduce in one tenth of a second the value of the critical gap. Also change the value for the follow-up headway in that access according to the value given by changing the critical gap in equation 3.6. Repeat until queues are replicated for the lanes at the access in study.
5. Then analyze the next access in the way that vehicles are circulating (Clock-wise for Chile). Repeat previous point for that access until queues are replicated.
6. Go ahead in a circular way. If the calibration of any *j+k* access gets worst any of the access already calibrated between the *j* (first one calibrated) and the *j+k-1*, the process retreat to the access with the problem.
7. The end of the process is given when the differences in maximum queues for all lanes is less than the errors accepted by the modeler.

During all the process the following error index was used:

$$Error = \frac{\sum_{i=1}^{l} \left| (realMAXqueue_i - simMAXqueue_i) \right|}{\sum_{i=1}^{l} realMAXqueue_i} \qquad l = N^o \text{ of approaching lanes} \qquad (3.7)$$

This process is based on the improvement or worsening of the differences between queues in the real case and the simulated case. In fact, according to these differences it is decided to continue with the next access at the right or to go back to another one already calibrated. The error shown at the formula 3.7. is only a reference to know what is going on with the intersection and does not influence on the calibration process. That means that it does not influence in the election of which access will be calibrated next.

3.6. Validation

Following the definition of the validation process, after the calibration it was needed to perform another program run.

For the validation it was needed to make some new field analysis in order to find the origin destination flows and then run the program with the new O-D matrix and with the values of critical gap and follow-up headways obtained at the end of the calibration.
It is recommended to calibrate at the morning peak time and validate at the evening peak, because it can be assumed that driver may have similar behavior.

4. EXPERIMENTS

The field experiment was done in the Irene Frei roundabout at the city of Santiago in Chile. The roundabout has five access and a total of 13 entrance lanes. The data collection was done at 7:30 a.m. in a period of one hour. The queues and origin destination matrix were measured by 14 people. The main consideration was that the flow must be estimated by access lane because this information is required in order to change from lane data to movement data.

Five recordings were necessary: one for each access and were used for the estimation of the initial values of critical gaps and follow-up headways for each lane.

The three methods for estimating the critical gap were used. It was found that the second and the third one, both considering bivariate log-normal distribution, are not as good for Chilean roundabouts. The reason for this is that driver behavior is quite random and many of them do not respect circulating lanes. That reduces dramatically the number of observations that are useful to use the maximum likelihood method.

After the data analysis, the initial values were converted from gaps and follow-up headways by lanes to gaps and follow-up headways by movement using the methodology described in point 3.4 and using the O-D disaggregated matrix by access showed at Table 1.

Then, two accesses (access 3 and access 4) were considered together to determine parameters values. The aaSIDRA model considers parameters by movements and it does not have a definition for more than 3 movements. Nevertheless this is only for the parameters definition and has no relationship with the O-D matrix input that is considered complete including 5 access and the 5 exists.

The value of C_j^i was calculated for each movement of each access and it was found that in fact the values are close to 0,6 or 0,7

Table 2 shows the difference between the maximum queue observed and the maximum queue simulated for each lane at the beginning of the calibration. In first place these differences are shown for the initial simulation in which aaSIDRA estimates the parameter values. Then, at the right side of the table, the initial run of the calibration can be seen in which the values for critical gap and follow-up headways are estimated with the field data converted to parameters by movement. It can also be seen that both simulations give big errors.

The cycling queue replication process began with the 76% of error and finished with an 8% of total error. See Table 3.

For this research it can be setup that an acceptable error is a 3 vehicles difference for each lane between the simulated case and the calibrated case. That means that if at the calibration of any access, all lanes have an error of less that 3 vehicles the process continues to the next access. It is important to say that if at any iteration of the process an error bigger than three vehicles is observed , is due to the fact that it is because is impossible to reduce it any more.

For the validation process, another run of the program was made in another period of the day using the final values of the parameters from the calibration. The new O-D matrix was measured from 19:00 to 19:30 (Table 1) at the same intersection and on Table 4 it can seen the result of the process. For the new period of simulation, aaSIDRA estimates the parameters giving queue errors of 82%. If the parameters that were measured directly from field observation are used, the errors are 52%. This is the calibration recommended by the aaSIDRA user manual. Finally, using the new proposed calibration to estimate the parameter values in a circular way, the error goes down to only 19%.

5. CONCLUSSIONS

It was found that big errors on queue lengths appear if a calibration process is not taken into account with the degree of detail that it deserves. In general terms it was observed that without a calibration there is an error of 82%, while calibrating according to the aaSIDRA user manual and with this new cycling methodology the error is reduced to 58% and less than 19% respectively when validating.

A methodology for roundabouts calibration was designed and used, and demonstrated to be useful and logical.

It was demonstrated that the Chilean drivers seems to have shorter critical gaps than Australians and to have also a worse driving behavior.

It was also demonstrated that the ratio between the follow-up headway and the critical gap is similar to 0,6. The same value was found in Australia where aaSidra was designed..

The cycling calibration designed in the research seems to be the faster procedure with only 7 iterations for the case studied comparing with any other procedure.

This work shows that errors in roundabouts calibration can be diminished and this kind of intersections can be considered to use them in cases of low and medium demand.

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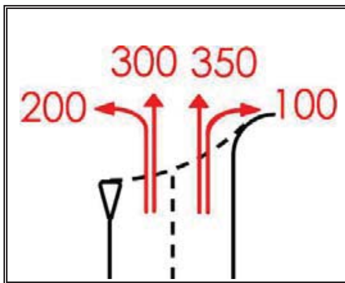

- Outer lane has g_c = 4,6 seconds
- Inner lane has g_c = 5,3 seconds

1) For right turns we keep g_c = 4,6 seconds
2) For left turns we keep g_c = 5,3 seconds
3) For vehicles that go throw:

$$g_c = \frac{350 \cdot 4{,}6 + 300 \cdot 5.3}{350 + 300} = 4{,}9 \text{ seconds}$$

Figure 1: Changing gaps by lane to gaps by movement (two lane access)

Table 1: O-D Matrix for calibration and O-D matrix for validation

	S1	S2	S3	S4	S5	
A1.1	23	124	192	309	55	704
A1.2	39	7	143	352	121	661
A1.3	39	3	52	195	283	573
A2.1	10	26	10	55	85	186
A2.2	62	10	7	26	176	280
A2.3	78	10	3	13	134	238
A3.1	173	39	33	26	49	319
A3.2	140	33	20	26	7	225
A4.1	218	26	23	33	36	336
A4.2	166	65	13	23	13	280
A5.1	179	94	10	13	55	352
A5.2	3	140	13	7	3	166
A5.3	3	78	13	10	16	121
	1134	655	531	1088	1033	4440

	S1	S2	S3	S4	S5	
A1	26	182	195	429	247	1.079
A2	123	25	25	49	221	443
A3	175	60	0	26	55	316
A4	350	58	0	0	11	419
A5	308	338	41	41	0	728
	982	663	261	545	534	2.985

Table 2: Starting point of calibration

		Variables Estimadas por aaSIDRA			Variables Estimadas en Terreno		
		Cola Máxima Observada (veh)	Cola Maxima Simulada (veh)	DIF (veh)	Cola Máxima Observada (veh)	Cola Máxima Simulada (veh)	DIF (veh)
A5.3	Vitac W 1LT	3	1,7	1,3	3	2,2	0,8
A5.2	Vitac W 2 T	4	1,5	2,5	4	2,1	1,9
A5.1	Vitac W 3 TR	5	1,6	3,4	5	2,2	2,8
A1.3	Manq S 1LT	8	7,4	0,6	8	12,7	4,7
A1.2	Manq S 2 T	12	7,0	5,0	12	12,7	0,7
A1.1	Manq S 3 TR	11	7,0	4,0	11	12,7	1,7
A2.3	Vitac E 1 LT	18	5,9	12,1	18	62,3	44,3
A2.2	Vitac E 2 T	18	4,4	13,6	18	61,9	43,9
A2.1	Vitac E 3 TR	14	4,4	9,6	14	14,9	0,9
A3.2	Juan XXIII 1 LT	52	75,4	23,4	52	29,9	22,1
A3.1	Juan XXIII 2 TR	11	11,3	0,3	11	11,3	0,3
A4.2	Manq N 1 LT	14	81,1	67,1	14	28,9	14,9
A4.1	Manq N 2 TR	13	13,1	0,1	13	13,1	0,1
	ERROR (veh):			142,9			139,0
	ERROR (%):			78%			76%

Table 3: Calibration procedure

	Initial Simulation			Simulation 1			Simulation 2			Simulation 3		
				Calibration Vitac E			Calibration J: XXIII			Calibration Manq N		
Max Observed queue (veh)	Max Simulated queue (veh)	DIF (veh)	Action	Max Simulated queue (veh)	DIF (veh)	Action	Max Simulated queue (veh)	DIF (veh)	Action	Max Simulated queue (veh)	DIF (veh)	Action
3	2,2	0,8	OK	2,1	0,9	OK	2,1	0,9	OK	2,3	0,7	OK
4	2,1	1,9	OK	2	2	OK	2	2	OK	2,2	1,8	OK
5	2,2	2,8	OK	2	3	OK	2	3	OK	2,3	2,7	OK
8	12,7	4,7	Dism	9,9	1,9	OK	10,2	2,2	OK	13,2	5,2	Dism
12	12,7	0,7	OK	9,9	2,1	OK	10,2	1,8	OK	13,2	1,2	OK
11	12,7	1,7	OK	9,9	1,1	OK	10,2	0,8	OK	13,2	2,2	OK
18	62,3	44,3	Dism	15,4	2,6	OK	16,8	1,2	OK	33,6	15,6	Dism
18	61,9	43,9	Dism	14	4	Dism	15,2	2,8	OK	30,4	12,4	Dism
14	14,9	0,9	OK	13,2	0,8	OK	14,3	0,3	OK	14,7	0,7	OK
52	29,9	22,1	Dism	69,1	17,1	Dism	51	1	OK	49,2	2,8	OK
11	11,3	0,3	OK	11,3	0,3	OK	11,3	0,3	OK	11,3	0,3	OK
14	28,9	14,9	Dism	96,1	82,1	Dism	105,5	91,5	Dism	15,2	1,2	OK
13	13,1	0,1	OK	13,1	0,1	OK	13,1	0,1	OK	13,1	0,1	OK
Error (veh)		139			118			108			47	
Error (%)		76%			64%			59%			26%	

	Initial Simulation			Simulation 1			Simulation 2			Simulation 3		
				Calibration Vitac E			Calibration J: XXIII			Calibration Manq N		
Max Observed queue (veh)	Max Simulated queue (veh)	DIF (veh)	Action	Max Simulated queue (veh)	DIF (veh)	Action	Max Simulated queue (veh)	DIF (veh)	Action	Max Simulated queue (veh)	DIF (veh)	Action
3	2,4	0,6	OK	2,4	0,6	OK	2,4	0,6	OK	2,4	0,6	OK
4	2,3	1,7	OK	2,3	1,7	OK	2,3	1,7	OK	2,4	1,6	OK
5	2,3	2,7	OK	2,3	2,7	OK	2,4	2,6	OK	2,4	2,6	OK
8	9,8	1,8	OK	9,6	1,6	OK	9,7	1,7	OK	9,9	1,9	OK
12	9,8	2,2	OK	9,6	2,4	OK	9,7	2,3	OK	9,9	2,1	OK
11	9,7	1,3	OK	9,5	1,5	OK	9,6	1,4	OK	9,7	1,3	OK
18	28,3	10,3	Dism	17,7	0,3	OK	18,3	0,3	OK	18,9	0,9	OK
18	25,7	7,7	Dism	16,6	1,4	OK	17,1	0,9	OK	17,7	0,3	OK
14	14,9	0,9	OK	14,9	0,9	OK	14,8	0,8	OK	15	1	OK
52	50,2	1,8	OK	63,4	11,4	Dism	54,6	2,6	OK	54,5	2,5	OK
11	11,3	0,3	OK	11,3	0,3	OK	11,3	0,3	OK	11,3	0,3	OK
14	17,4	3,4	Dism	22,9	8,9	Dism	25,8	11,8	Dism	14,4	0,4	OK
13	13,1	0,1	OK	13,1	0,1	OK	13,1	0,1	OK	13,1	0,1	OK
Error (veh)		34,7			33,7			27			15,5	
Error (%)		19%			18%			15%			8%	

Table 4: Validation procedure

			Simulation with parameters estimated by aaSIDRA		Simulation with parameters estimated on field		Simulation with parameters founded with the cicling process	
		Max Observed queue (veh)	Max Simulated queue (veh)	DIF (veh)	Max Simulated queue (veh)	DIF (veh)	Max Simulated queue (veh)	DIF (veh)
A5.3	Vitac W 1LT	31	6,5	24,5	16,9	14,1	30,7	0,3
A5.2	Vitac W 2 T	27	5,5	21,5	16,9	10,1	30,2	3,2
A5.1	Vitac W 3 TR	25	6,4	18,6	26,8	1,8	40,6	15,6
A1.3	Manq S 1LT	46	20,8	25,2	67,5	21,5	41,7	4,3
A1.2	Manq S 2 T	46	17,8	28,2	67,5	21,5	41,7	4,3
A1.1	Manq S 3 TR	37	17,8	19,2	67,5	30,5	39,7	2,7
A2.3	Vitac E 1 LT	21	8,3	12,7	6,2	14,8	9,2	11,8
A2.2	Vitac E 2 T	17	5,9	11,1	5,9	11,1	8,3	8,7
A2.1	Vitac E 3 TR	9	6,1	2,9	6,1	2,9	7,9	1,1
A3.2	Juan XXIII 1 LT	24	60	36	8,5	15,5	18,3	5,7
A3.1	Juan XXIII 2 TR	10	11,2	1,2	8,3	1,7	11,3	1,3
A4.2	Manq N 1 LT	29	101	72	76,5	47,5	34,9	5,9
A4.1	Manq N 2 TR	12	13	1	13,1	1,1	13,1	1,1
	ERROR (veh):			273,1		193,3		64,9
	ERROR (%):			82%		58%		19%