SIDRA SOLUTIONS®

Akcelik & Associates Pty Ltd
PO Box 1075G, Greythorn, Vic 3104 AUSTRALIA
info@sidrasolutions.com

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REPRINT

SIDRA-2 does it lane by lane

R. AKÇELIK

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NOTE:

This paper is related to the intersection analysis methodology used in the SIDRA INTERSECTION software. Since the publication of this paper, many related aspects of the traffic model have been further developed in later versions of SIDRA INTERSECTION. Though some aspects of this paper may be outdated, this reprint is provided as a record of important aspects of the SIDRA INTERSECTION software, and in order to promote software assessment and further research.

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SIDRA-2 DOES IT LANE BY LANE

R. AKCELIK, Ph.D., M.I.E.Aust., M.I.T.E., Principal Research Scientist, Australian Road Research Board.

ABSTRACT

SIDRA-2 has been developed as a computer program to aid traffic engineers and researchers in the design and analysis of signalised intersections. SIDRA-2 implements the techniques described in the ARRB Research Report ARR No. 123 (Traffic Signals: Capacity and Timing Analysis). Although the fundamental principles and methods are the same, there are some important differences between ARR No. 123 and SIDRA-2. The most important is the lane-by-lane calculation of capacities and operating characteristics such as delay, number of stops and queue length. This paper outlines the main features of SIDRA-2 and discusses various aspects of the new method of lane-by-lane calculations. The 'lane interaction' and 'opposed turn' models are described briefly. Lane-by-lane calculations allow for the use of different lost times, hence different effective green and red times, for different lanes, which improve the results for operating characteristics. This also improves the capacity predictions. The use of the 'opposed turn equivalents' (e_0) and other movement saturation flow adjustments, e.g. for lane under-utilisation, are no longer necessary. The paper discusses a problem in the theory of signal design which is related to the application of the formulae for delays, etc. on a lane-by-lane against movement-by-movement basis. A full intersection example is given to illustrate the use of SIDRA-2.

INTRODUCTION

1. ARRB Research Report ARR No. 123 (Akcelik 1981) introduced various improvements to traditional techniques of capacity and timing calculations for signalised intersections. The response to the publication has been satisfactory and it is understood that the report is being widely used in both practice and teaching in Australia and New Zealand. There has been interest from many other countries such as U.K., Poland, China, and Canada. Some aspects of ARR No. 123 have been adapted into the revised U.S. Highway Capacity Manual which is under development (JHK and Assoc. 1982). It has received favourable comments in a recent OECD Road Research Report (OECD 1983). Another recent study conducted in the U.S.A. compared eight methods of signalised intersection capacity analysis including the British (Webster and Cobbe 1966), Swedish (Peterson, Hansson and Bang 1978), Australian (Akcelik 1981) and five U.S. methods, and found that the Australian and a new U.S. method (JHK and Assoc. 1982) were the most cost-effective methods. ARR No. 123 has been re-printed twice since its first publication in 1981. The latest re-print incorporates several minor changes, but it is basically the same as the original publication.

2. It had been recognised before the first publication of ARR No. 123 that there was a need for a computer program to implement the techniques given in the report for the reasons of improved computing efficiency and accuracy. It was decided to use the existing SIDRA program (Akcelik 1979) as a basis for developing a new program which incorporates the new techniques of ARR No. 123. The original version of SIDRA had not been released formally, but some use of the program had been made in design and teaching. Although the new program is called SIDRA version 2, it is

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substantially different from the original SIDRA. Furthermore, SIDRA-2 has some advanced features not included in ARR No. 123. An important feature is the adoption of a lane-by-lane method for capacity and performance calculations. The main features of SIDRA-2 are summarised in the following section followed by a detailed description of the lane-by-lane computation method.

SIDRA-2

3. SIDRA-2 uses the analytical models of ARR No. 123 rather than a simulation model. This yields high efficiency in computing time usage and gives a unique set of results to the traffic engineer. SIDRA-2 allows for the effects of randomness and oversaturation through the use of the overflow queue concept described in ARR No. 123. Thus, the capacity effects are allowed for in a sufficiently accurate and efficient way without need for detailed simulation. This basic approach is also used in the TRANSYT program (Vincent, Mitchell and Robertson 1980) for a network of traffic signals although its deterministic calculations involve a simulation-like method. Another program which has been used in Australia for single intersection calculations, SIMSET2, employs separate simulation models for uniform and random arrivals (Sims 1980), and is used in either the uniform or the random arrival mode. The two SIMSET models are different to those in SIDRA, and will therefore lead to different performance predictions and, sometimes, different timing results. Other diffences between the two programs are that SIDRA, being non-simulation based, is faster and produces reproducible results for random arrivals.

4. SIDRA-2 can determine signal timings for very complex phasing arrangements with any combination of overlaps, minimum and maximum constraints, and two separate green periods per cycle. This is achieved through the use of the critical movement identification technique of ARR No. 123. The emphasis is on the use of 'practical', rather than 'optimum' signal timing solutions (see ARR No. 123 for the usage of these terms). Thus, hill-climbing type search procedures are not used in SIDRA-2. While an 'optimum' solution indicates the best possible timings for a given design depending on the criteria used, the 'practical' solution tends to indicate the weaknesses of the design. For example, in real life, long maximum green time settings could result in reduced short lane capacities, and hence, congested conditions. SIDRA-2 solution corresponds to this situation where the cycle length increases as the conditions get worse and the longer cycle time causes further deterioration of the conditions. In such cases, SIDRA-2 gives a maximum cycle time solution with high degrees of saturation, which reflects what happens in real life. An 'optimum' solution may not indicate this problem.

5. In SIDRA-2, individual movements are the basis of timing calculations as in ARR No. 123. Lane capacity estimates are converted to movement saturation flow values using the method of ARR No. 123 and then used for timing calculations. For a set of signal timings (the cycle time and green times) which may be user-specified or computed, SIDRA-2 calculates the estimates of delay, number of stops and queue length. This is done using extended forms of the formulae given in ARR No. 123 which cover the case of two green periods per cycle. Furthermore, the performance formulae are applied on a lane-by-lane basis whereas they are used on a movement-by-movement basis in ARR No. 123. This is discussed in detail later in the paper.

6. The most important feature of SIDRA-2 which was not available in the original version is the facility to estimate saturation flows. This facility is particularly useful in the complicated cases of opposed turns and short lanes where manual calculations are often tedious and not accurate in some cases. Although formulae are given in ARR No. 123 for calculating lane flows, this has not been specified as a necessary part of the capacity estimation procedure. This was partly due to an effort not to differ too much from the earlier techniques and partly because the manual calculations would be tedious. A lane-by-lane method for saturation flow estimation had already been used in the Swedish method (Peterson, et al. 1978) and a computer program was developed for its execution (Hansson 1980). Discussions on the calculation of lane flows can also be found in Getao and Van Vliet (1980) and Akcelik (1980). In a paper presented at the 11th ARRB Conference, Dunn (1982) showed the types of error that may result when lane flows are not calculated. At the early stages of SIDRA-2 development, a mixture of lane-based and movement-based capacity estimation methods were being used. However, mainly as a consequence of the development of a solution to the

'lane interaction' problem, a completely lane-based capacity estimation method was finally adopted. This is explained in the following paragraphs.

'LANE INTERACTION' PROBLEM AND OPPOSED TURNS

7. It is quite common to find a lane allocated to two movements which receive right of way at different times during the signal cycle. For example, through and right-turning traffic in a lane where right-turning traffic can depart freely in one green period (green arrow) and have to filter through the opposing traffic in another (green disc) while through traffic can depart during both periods. In this case, there is not a clearly defined 'green period' for the lane since the two movements will block each other and/or will depart together at different times. As such, the lane will have characteristics different from the other lanes of both movements. The most efficient and general method to this problem has been found by the adoption of a capacity estimation process which treats individual lanes of a movement (or several movements) from an approach road separately. As an essential feature of the lane-by-lane method, SIDRA-2 calculates the lost times and effective green and red times for each lane of each movement separately. The movements which have a lane in common (i.e. interacting) are treated together and the lane in common is uniquely defined.

8. Opposed turns in shared lanes, e.g. through and right-turn lanes, can be considered to be a special case of lane interaction. In ARR No. 123, opposed turn equivalents (e_0) are calculated for shared lanes, while a lost time (and green time) adjustment method has been described for opposed turns from an exclusive lane. The adoption of the lane-by-lane method has allowed the use of the lost time adjustment method for the shared lanes also since different green times and lost times can be used for different lanes of the same movement. Thus, the e_0 method is no longer used in SIDRA-2.

9. The opposed turn method has been further improved by allowing for any departures of unopposed traffic (e.g. through) from the shared lane before being blocked by the opposed traffic (e.g. right-turns). Calculations are based on a probability formula given by Hegarty and Pretty (1982). SIDRA-2 allows for up to four opposing movements with different flow and timing characteristics. A special algorithm is employed to process all the opposing movements to find the intervals during which departures by gap-acceptance can occur. Departure rates are calculated according to whether several opposing movements run together or not, and whether an opposing movement itself is opposed by another movement.

10. The opposed turn capacity estimation method of ARR No. 123 is further improved in SIDRA-2 by considering each lane of each opposing movement individually. The end of saturation in any lane of the opposing movement can be found more accurately since any lane under-utilisation effect is explicitly accounted for, i.e. there are no averaging effects. The saturation flow of opposed turns while they can depart by accepting gaps in the opposing stream is calculated using a method described by Gipps (1982). The method involves the calculation of saturation flow as a function of opposing lane flows rather than the total opposing flow.

ESTIMATION OF LANE FLOWS AND CAPACITIES

11. For a set of signal timings, SIDRA-2 estimates lane flows and capacities as follows. The lane flows are calculated according to the principle of equal degrees of saturation as described in ARR No. 123. The specified lane disciplines and maximum turning flows are considered in the process of calculating lane flows. This may lead to lane under-utilisation. For example, a lane specified as a through and right-turn lane may be allocated to right-turn traffic only because the degree of saturation of the lane is higher than the adjacent lanes which are available to through vehicles. Because the lane flows and capacities are inter-dependent, they are computed using an iterative process. Further iterations are carried out to re-adjust capacities due to the changing conditions of opposed turns and short lanes as lane flows change.

12. When a consistent set of lane flows and capacities are found at the end of iterations, the capacity values are converted to movement saturation flow values using the basic relationships given in ARR No. 123. Any under-utilisation or effective green time differences of individual

lanes are taken into account in this process. In the case of lane interaction, the saturation flows are calculated in such a way that the degrees of saturation of the movements involved in lane interaction are not changed.

13. Signal timings (cycle time and phase change times) are calculated using the movement saturation flows which are estimated as described above. Since the timings and saturation flows are inter-dependent, iterations are carried out to find a consistent set of results. In SIDRA-2, these are called main iterations to distinguish them from sub-iterations for lane flow and capacity calculations. Up to ten main iterations are allowed. There are cases where equilibrium can not be achieved which are reported by the program.

14. It should be emphasised that the 'saturation flows' calculated by SIDRA-2 as described above are quite different from the basic saturation flows which are independent of signal timings. These are, rather, secondary statistics calculated from primary lane capacity values. Because lane capacities are determined by opposed turn, short lane and lane interaction characteristics which are strongly timing dependent, the resulting saturation flows are similarly timing dependent. The difference between SIDRA-2 and other computer programs which use constant (user-specified) saturation flows, e.g. SIGSET and SIGCAP (Allsop 1976, 1981) and TRANSYT (Vincent, et al. 1980) is very important. For example, the spare capacity results based on the assumption of constant saturation flows become rather misleading. It is also important to note that, unlike the assumption made in traditional theory, the capacity function is not necessarily continuous in all cases. SIDRA-2 indicates many cases of discontinuity which are due to changes in lane utilisation.

OPERATING CHARACTERISTICS

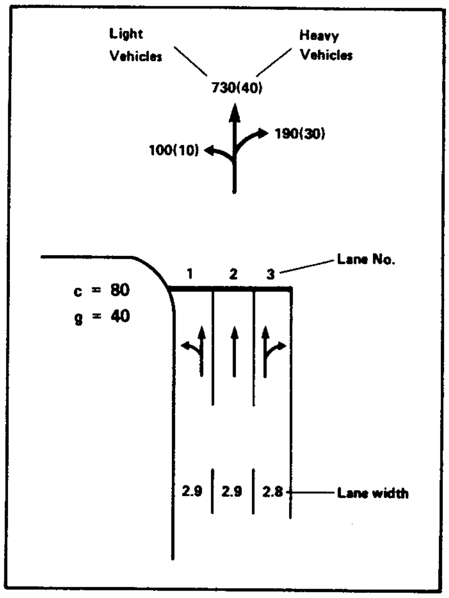
15. In ARR No. 123, it is recommended that the formulae for delay, number of stops and queue length are used on a movement-by-movement basis. While this is convenient for manual calculations, the accuracy has been improved in SIDRA-2 by applying the formulae to each lane individually. The improved accuracy is related to the cases of lane under-utilisation, opposed turns, short lanes and lane interaction. It should be noted that ARR No. 123 recommends the description of under-utilised lanes and exclusive lanes as separate movements so as to reduce possible errors in the calculation of operating characteristics. Extension to the lane interaction case is possible but it has been found that it is better to treat a lane involved in interaction on its own rather than as part of the two movements which share the lane.

16. There is another aspect of the calculation of operating characteristics which has important implications in terms of both practice and theory of signal design. Considering a simple movement with equal lane utilisation (i.e. equal degrees of saturation), the overflow queue values calculated on a lane-by-lane basis do not add up to the overflow queue value calculated for the movement as a whole. In the case of lane under-utilisation, the problem becomes more serious. In terms of the Webster delay formula (Webster and Cobbe 1966), or the method of the TRANSYT program (Vincent, et al. 1980), this corresponds to the fact that the same 'random delay' value will be calculated once for the movement as a whole as against for each lane of the movement repeatedly.

17. The calculations on a movement-by-movement basis may lead to misleading results in signal design which can be explained by means of an example: suppose a design option involves the description of the two lanes of an approach road as two movements whereas a second design option involves the description of the two lanes as one movement. In this case, the first design option would be penalised because of the additional delay, number of stops, etc. calculated as a result of the movement description. It should be emphasised that all existing methods/computer programs which do not use a lane-by-lane method for the calculation of operating characteristics will have this problem.

18. The simple example in Fig. 1 is used to show the difference between calculating operating characteristics on a lane-by-lane basis and on a movement-by-movement basis. It should be noted that there are no opposed turns, lane under-utilisation or short lanes in this example. The data for the example is taken from ARR No. 123, Section 9, Example 9.1, case (c). The data, together with the SIDRA-2 estimates of lane flows and saturation flows are given in Fig. 1. The flows

Data



SIDRA-2 Estimates of Lane Flows and Saturation Flows

Lane No.	Flow	Sat. Flow
1	334	1408
2	399	1681
3	367	1546
Total	1100	4635

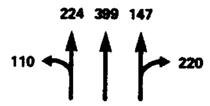


Fig. 1 - An example for lane-by-lane method of calculating performance statistics: Data and SIDRA-2 estimates of lane flows and saturation flows

given in Fig. 1 present a case of low degree of saturation ($x = 0.475$). A case of high degree of saturation is also considered using the same example with the flows doubled ($x = 0.949$).

19. The total delay estimates in veh-h/h are summarised in Table I. For comparison with the results based on the ARR No. 123 formula, the results from the well-known Webster delay formula are also given. The sum of the delay values obtained by applying the ARR No. 123 formula for each lane separately corresponds to the value printed out by SIDRA-2. Comparison of the sum of lane delay values with the value of delay calculated when all lanes are treated as one movement shows that very large differences may result for high degrees of saturation using both the ARR No. 123 formula and the Webster formula. As seen in Table I, the sum of lane delay values equals the movement delay for low degrees of saturation with the ARR No. 123 formula. This is because the overflow term is zero and the uniform components are additive (this does not apply to the Webster formula). In general, the differences between the results from the lane-by-lane method and the movement-by-movement method become particularly large when there is lane under-utilisation and the degree of saturation of the under-utilised lane is low while the degree of saturation of the other lane(s) is high.

20. Ideally, the lane flows and capacities should be estimated as in SIDRA-2 and the operating characteristics should be calculated using these values. However, the following simplified method can be used to calculate operating characteristics without finding individual lane values for the purposes of manual calculations. Referring to the formulae in Section 6 of ARR No. 123, the green time ratio, flow ratio and the degree of saturation are assumed to be the same for all lanes and the same as the movement value. Find the average lane flow and capacity values by dividing the movement flow and capacity by the number of lanes ($q_i = q/n$, $Q_i = Q/n$). Calculate $(sg)_i = Q_i c/3600$ to calculate x_{0i} value for the lane. Use Q_i and x_{0i} in eqn (6.1) of ARR No. 123 to calculate the overflow queue for an average lane, N_{0i}. Use q_i and N_{0i} to find total delay, number of stops and the maximum back of the queue for the lane, D_i, H_i and N_{mi}. The total delay and number of stops for the movement are $D = nD_i$ and $H = nH_i$, and N_{mi} can be used as the maximum back of the queue in any lane. Although this method gives an approximate solution, it is compatible with the method adapted in SIDRA-2 and as such it avoids the problems discussed above.

AN EXAMPLE

21. A full intersection example to illustrate the SIDRA method of estimating lane flows, capacities and operating characteristics is given in Fig. 2. This is the intersection of Great Western Highway and Church

TABLE I

TOTAL DELAYS IN VEH-H/H FOR THE EXAMPLE IN FIG. 1

Movement Description	Low Degree of Saturation: x = 0.475		High Degree of Saturation: x = 0.949	
	ARR No. 123 Formula	Webster * Formula	ARR No. 123 Formula	Webster * Formula
Lane 1	1.22	1.29	8.89	11.11
Lane 2	1.45	1.50	9.72	11.81
Lane 3	1.34	1.40	9.35	11.53
Sum	4.01†	4.19	27.96†	34.45
All Lanes ††	4.01	3.18	16.62	18.50

* Webster's simplified formula (in ARR No. 123 notation):

$$D = 0.9\left[\frac{qc(1-u)^2}{2(1-y)} + \frac{x^2}{2(1-x)}\right]$$

† SIDRA-2 solution for movement delay

†† Lanes 1, 2 and 3 together treated as a single movement without attention to individual lanes

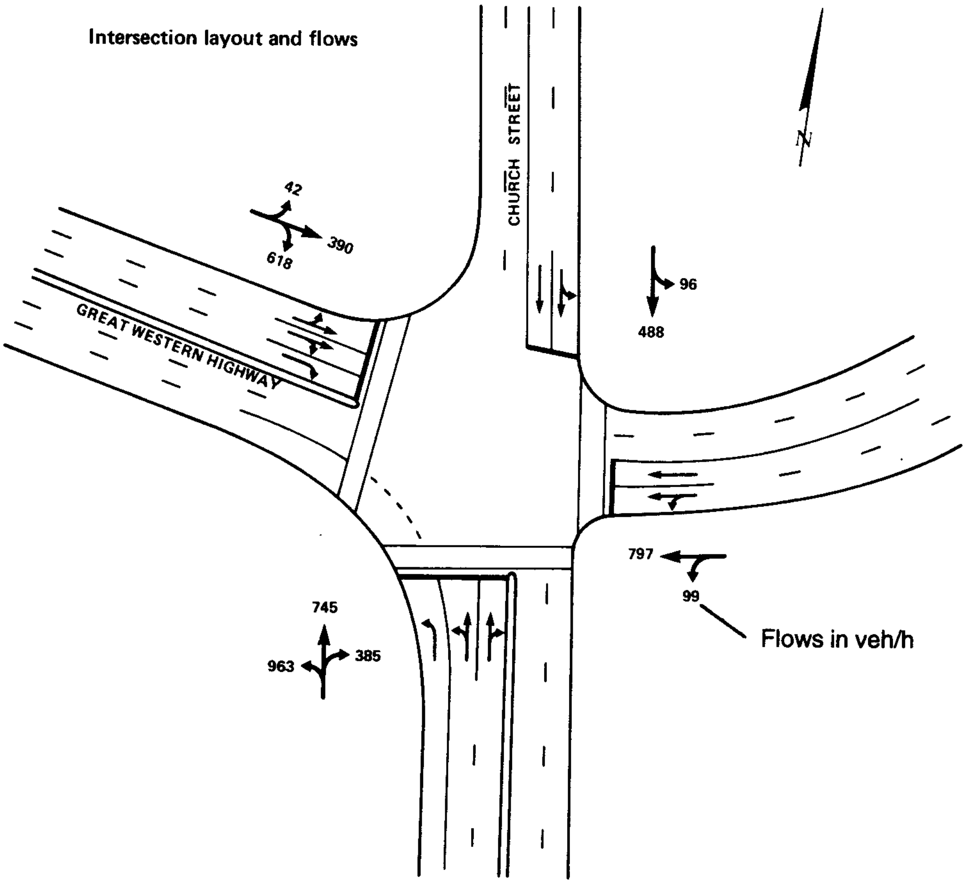
Street in Parramatta, New South Wales. Luk, Lowrie and Sims (1982) discussed the difficulties of modelling this intersection for TRANSYT in some detail. This intersection presents lane interaction problems in the West and South approach roads, the latter being a more complicated case. There are no opposed turns. Note that left-turning movement from the South approach road (Movement 1086) is described as having two green periods with a start lag of 28 s for the first green. This is due to the conflicting pedestrian movement. Individual lane saturation flows which had been measured in the field are specified to SIDRA as input. Cycle time is specified as 140 s and various constraints described in Luk, et al. (1982) are used.

22. Full SIDRA-2 output for this example is given in Figs 3 (a) to (e). Input data are summarised in the first page of the output as seen in Fig. 3(a). The listing of movement saturation flows, capacities, etc. and the results of timing calculations are seen in Fig. 3(b). The phase change times found by SIDRA-2 are (0, 31, 76, 115). These are very close to the times used by Luk, et al. (1982) which are (0, 30, 74, 115). In Fig. 3(c), operating characteristics are summarised in two tables, one for movements and one for individual lanes. The movement statistics are grouped by approach road in accordance with input specification. The details of lane flows, capacities, etc. can be seen in Fig. 3(d). It is seen that a solution with equal degrees of saturation is achieved for the lanes allocated to movements 1084, 1085 and 1086. On the other hand, there is unequal lane utilisation in the West approach road (movements 1080 and 1081): no through vehicles will use the centre lane because the conditions are much worse in that lane. Finally, the timing diagram in Fig. 3(e) illustrates phase change times and effective green and red times for movements (G denotes green period).

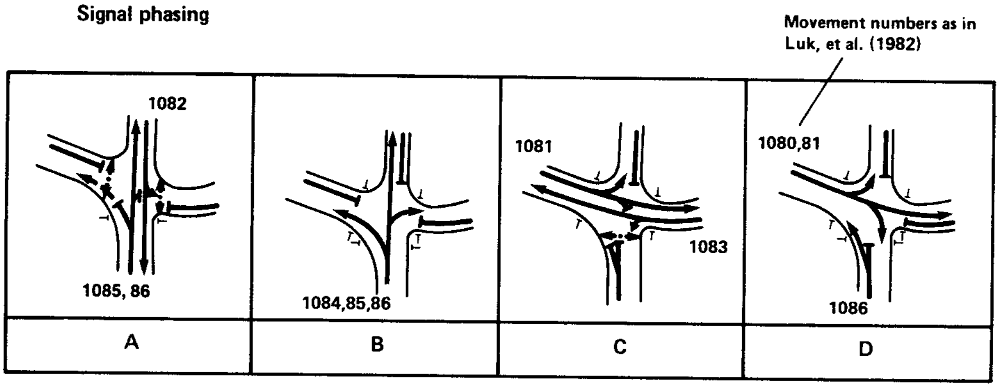
DEVELOPMENT OF SIDRA-2

23. Two trial workshops were held during the development of SIDRA-2. The majority of workshop attendees were traffic engineers from State Road Authorities who used SIDRA-2 to solve their own real-life design problems. This helped to identify the areas of program improvement. As a result, several trivial error conditions have been removed (mostly to do with input errors), a comprehensive set of error

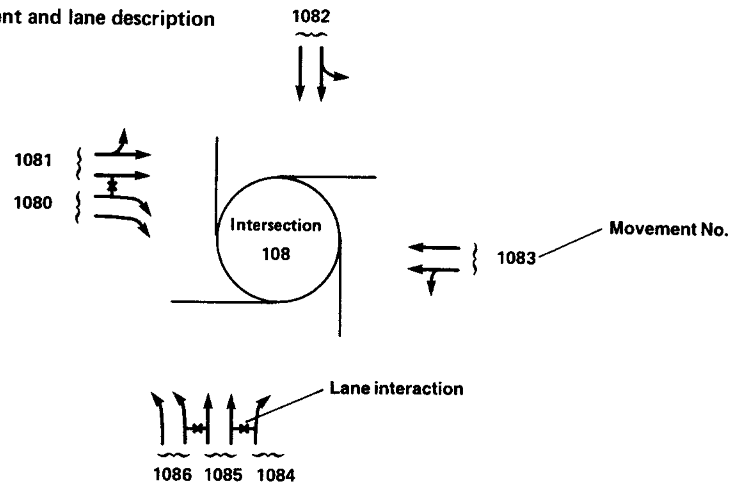
Intersection layout and flows



Signal phasing



Movement and lane description



S I D R A 2

LUK, LOWRIE AND SIMS - INTERSECTION 108 PARRAMATTA (C=140) ...... * ARRB12 * 84/02/09.

INPUT DATA

CONTROL CARD

CARD NO.	CARD TYPE	NO.OF PHASES	NO.OF MOVS	CYCLE TIME	CYCLE INCR.	MAX. CYCLE	OUTPUT OPTIONS	STOP PENAL.	FLOW PERIOD	FLOW SCALE	HV DATA OPTIONS	UNIT TIME	SATN.FLOW SCALE
1	1	4	7	140	10*	180*	111	20	60*	100*	0	60*	100*

MOVEMENT DATA: PHASE AND TIMING PARAMETERS

			FIRST GREEN							SECOND GREEN						
CARD NO.	CARD TYPE	MOV. NO.	START PHASE	END PHASE	INTER-GREEN	START LOSS	END GAIN	MIN. GREEN	MAX. GREEN	START PHASE	END PHASE	INTER-GREEN	START LOSS	END GAIN	MIN. GREEN	MAX. GREEN
2	4	1080	4	1	5	2	3	20	20	0	0	0	0	0	0	0
3	4	1081	3	1	4	2	3	6*	0	0	0	0	0	0	0	0
4	4	1082	1	2	5	2	3	23	0	0	0	0	0	0	0	0
5	4	1083	3	4	4	2	3	22	0	0	0	0	0	0	0	0
6	4	1084	2	3	4	2	3	20	0	0	0	0	0	0	0	0
7	4	1085	1	3	5	2	3	6*	0	0	0	0	0	0	0	0
8	4	1086	1	3	26	2	3	6*	0	4	1	5	2	3	6*	0

MOVEMENT DATA: FLOW AND SATURATION FLOW, PARAMETERS

				SATN FLOW						TURN TYPE/RADIUS		TRAFFIC COMPOSITION DATA (VEH/UNIT TIME)					
												LEFT		THROUGH		RIGHT	
CARD NO.	CARD TYPE	MOV. NO.	FLOW (VEH/H)	1ST GRN	2ND GRN	PRAC. DEG.SATN	GRAD. (%)	NO.OF LANES	ENV. CLASS	L	R	LV	HV	LV	HV	LV	HV
9	5	1080	0	0	0	100	0	2	1	0	0	0	0	0	0	618	0
10	5	1081	0	0	0	90*	0	2	1	0	0	42	0	390	0	0	0
11	5	1082	0	0	0	90*	0	2	1	0	0	96	0	488	0	0	0
12	5	1083	0	0	0	100	0	2	1	0	0	99	0	797	0	0	0
13	5	1084	0	0	0	90*	0	1	1	0	0	0	0	0	0	385	0
14	5	1085	0	0	0	90*	0	2	1	0	0	0	0	745	0	0	0
15	5	1086	0	0	0	90*	0	2	1	0	0	963	0	0	0	0	0

LANE DATA

CARD NO.	CARD TYPE	MOV. NO.	LANE NO.	LANE DISPLN	WIDTH (M*100)	BASE SAT.FLOW	LANE UTIL.	LENGTH (M)	GREEN CONSTR.	ADJACENT MOVEMENT NO. NOT COMMON	ADJACENT MOVEMENT NO. COMMON	FREE QUEUE
16	8	1080	1	3	330*	1863	100*	0	0	0	0	0
17	8	1080	2	3	330*	2131	100*	0	0	0	0	0
18	8	1081	1	4	330*	1826	100*	0	0	0	0	0
19	8	1081	2	1	330*	1863	100*	0	0	0	1080	0
20	8	1082	1	4	330*	1650	100*	0	0	0	0	0
21	8	1082	2	1	330*	1650	100*	0	0	0	0	0
22	8	1083	1	4	330*	1703	100*	0	0	0	0	0
23	8	1083	2	1	330*	1748	100*	0	0	0	0	0
24	8	1084	1	3	330*	1662	100*	0	0	0	0	0
25	8	1085	1	1	330*	1790	100*	0	0	0	0	0
26	8	1085	2	1	330*	1662	100*	0	0	0	1084	0
27	8	1086	1	2	330*	1867	100*	0	0	0	0	0
28	8	1086	2	2	330*	1790	100*	0	0	0	1085	0

GROUP DEFINITION

CARD NO.	CARD TYPE	GROUP NO.	GROUP LIST: MOV. NO.	MOV. NO.	MOV. NO.	MOV. NO.	MOV. NO.	MOV. NO.	MOV. NO.	MOV. NO.	GROUP DESCRIPTION
29	11	1	1080	1081							WEST APPROACH
30	11	2	1082								NORTH APPROACH
31	11	3	1083								EAST APPROACH
32	11	4	1084	1085	1086						SOUTH APPROACH

NOTE

DATA FLAGGED WITH A * INDICATES A DEFAULT VALUE ALLOCATED BY THE PROGRAM DUE TO ZERO OR BLANK USER INPUT.

Fig. 3(a) - SIDRA-2 output for the example in Fig. 2: input data listing

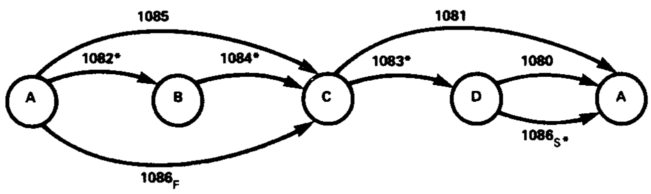
LUK, LOWRIE AND SIMS - INTERSECTION 108 PARRAMATTA (C=140) ...... * ARRB12 * 84/02/09.

BASIC DESIGN PARAMETERS CYCLE TIME = 140

MOV. NO.	PHASE MATRIX 1ST STR	GRN END	2ND STR	GRN END	FLOW (VEH/H)	SATN FLOW 1ST GRN	2ND GRN	LOST TIME 1ST GRN	2ND GRN	FLOW RATIO Y	PRAC. DEG. SATN XP	REQ.MOV.TIME 1ST GRN	2ND GRN	EFF. GRN 1ST GRN	2ND GRN	CAP. (VEH/H)	DEG. SATN X
1080	4	1			618	3994		4		.155	1.000	25MAX		21		599	1.032*
1081U	3	1			432	1826		3		.237	.900	40		61		796	.543
1082	1	2			584	3300		4		.177	.900	32		27		636	.918
1083	3	4			896	3451		3		.260	1.000	39		36		887	1.010
1084	2	3			385	1392		3		.277	.900	46		42		418	.922
1085	1	3			745	1571		4		.474	.900	78		72		808	.922
1086	1	3	4	1	963	2089	1891	25	4	.474C	.900	78	25	51	21	1045	.922

INTERSECTION PARAMETERS :

CRIT. MOV. NO.	LOST TIME	ADJUSTED LOST TIME,L	FLOW RATIO Y	REQUIRED GRN TIME RATIO,U
1082	4	4	.177	.197
1084	3	3	.277	.307
1083	3	3	.260	.260
1086S	4	4	.136	.151
TOTAL :	14	14	.849	.915



CYCLE TIME :

MINIMUM	-	103
MAXIMUM	-	180
APP. OPTIMUM	-	189
PRACTICAL	-	165
CHOSEN	-	140 AS SPECIFIED BY THE USER

DEGREE OF SATN : 1.032

PHASE INFORMATION :

PHASE NO.	CHANGE TIME	GREEN START	GREEN (S)	PROP. OF GRN+INTGRN
1	0	5	26	.221
2	31	35	41	.321
3	76	80	35	.279
4	115	120	20	.179

NO. OF MAIN ITERATIONS = 4

Fig. 3(b) - SIDRA-2 output for the example in Fig. 2:
results of timing calculations
(critical movement search diagram added)

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OPERATING CHARACTERISTICS CYCLE TIME = 140

MOV. NO.	FLOW (VEH/H)	DEG. SATN X	DISTANCE TRAVELLED (VEH-KM/H)	AVER. SPEED (KM/H)	TOTAL DELAY (VEH-H/H)	AVER. DELAY (SEC)	TOTAL STOPS (VEH/H)	STOP RATE	LONGEST QUEUE LANE NO.	SIZE (VEHS)	SIZE (M)	PERF. INDEX	FUEL RATE (ML/KM)
WEST APPROACH													
1080	618	1.032	309.00	7.93	33.81	197.0	1086	1.76	2	24.7	148	86.75	358.2
1081U	432	.543	216.00	30.41	3.50	29.2	287	.67	1	12.4	75	17.52	137.4
NORTH APPROACH													
1082	584	.918	292.00	14.66	15.05	92.8	668	1.14	1	14.4	87	47.63	223.7
EAST APPROACH													
1083	896	1.010	448.00	10.36	35.77	143.7	1330	1.48	2	29.0	174	100.61	291.1
SOUTH APPROACH													
1084	385	.922	192.50	17.58	7.74	72.4	403	1.05	1	21.0	126	27.41	198.3
1085	745	.922	372.50	21.52	11.10	53.6	904	1.21	1	30.5	183	47.04	185.1
1086	963	.922	481.50	26.75	9.98	37.3	1123	1.17	2	30.5	183	43.67	166.0

SUMMARY STATISTICS:

	TOTAL FLOW (VEH/H)	DISTANCE TRAVELLED (VEH-KM/H)	AVER. SPEED (KM/H)	TOTAL DELAY (VEH-H/H)	AVER. DELAY (SEC)	TOTAL STOPS (VEH/H)	STOP RATE	PERF. INDEX	FUEL RATE (ML/KM)	FUEL TOTAL (ML/H)
WEST APPROACH	1050	525.00	11.40	37.31	127.9	1373	1.31	104.27	267.3	140357
NORTH APPROACH	584	292.00	14.66	15.05	92.8	668	1.14	47.63	223.7	65316
EAST APPROACH	896	448.00	10.36	35.77	143.7	1330	1.48	100.61	291.1	130391
SOUTH APPROACH	2093	1046.50	22.62	28.82	49.6	2430	1.16	118.12	178.8	187072
ALL GROUPS	4623	2311.50	14.87	116.95	91.1	5801	1.25	370.63	226.3	523137

LANE OPERATING CHARACTERISTICS

MOV. NO.	LANE NO.	FLOW (VEH/H)	CAP. (VEH/H)	DEG. SATN X	TOTAL DELAY (VEH-H/H)	AVER. DELAY (SEC)	TOTAL STOPS (VEH/H)	BACK OF QUEUE (VEHS)	BACK OF QUEUE (M)
1082	1	292	318	.918	7.52	92.8	334	14.4	87
	2	292	318	.918	7.52	92.8	334	14.4	87
1083	1	442	438	1.010	17.72	144.3	658	28.4	171
	2	454	449	1.010	18.04	143.1	672	29.0	174
1081	1	432	796	.543	3.50	29.2	287	12.4	75
1081, 1080	2, 1	288	279	1.032	16.08	200.8	513	22.2	133
1080	2	330	320	1.032	17.73	193.6	572	24.7	148
1086	1	885	960	.922	8.87	36.1	1027	24.3	146
1086, 1085	2, 1	743	806	.922	10.61	51.4	916	30.5	183
1085, 1084	2, 1	465	504	.922	9.34	72.4	487	21.0	126

Fig. 3(c) - SIDRA-2 output for the example in Fig. 2: movement and lane operating characteristics

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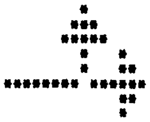
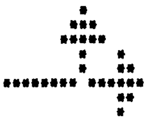
LANE FLOWS AND EFFECTIVE TIMINGS

CYCLE TIME = 140

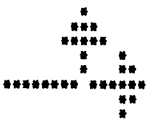
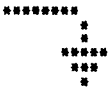
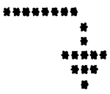
MOVEMENT NO. 1082

		FLOW (VEH/H) LEFT	THRU	RIGHT	TOTAL	SB TCU	S1 VEH	S2 VEH	G1 SEC	G2 SEC	R1 SEC	R2 SEC	CAP. VEH	DEG.OF SATN	RHO (%)
		96	196	0	292	1650	1650	0	27	0	113	0	318	.918	100.0
		0	292	0	292	1650	1650	0	27	0	113	0	318	.918	100.0

MOVEMENT NO. 1083

		FLOW (VEH/H) LEFT	THRU	RIGHT	TOTAL	SB TCU	S1 VEH	S2 VEH	G1 SEC	G2 SEC	R1 SEC	R2 SEC	CAP. VEH	DEG.OF SATN	RHO (%)
		99	343	0	442	1703	1703	0	36	0	104	0	438	1.010	100.0
		0	454	0	454	1748	1748	0	36	0	104	0	449	1.010	100.0

MOVEMENT NO. 1081, 1080

		FLOW (VEH/H) LEFT	THRU	RIGHT	TOTAL	SB TCU	S1 VEH	S2 VEH	G1 SEC	G2 SEC	R1 SEC	R2 SEC	CAP. VEH	DEG.OF SATN	RHO (%)
	1081	42	390	0	432	1826	1826	0	61	0	79	0	796	.543	52.6*
	1081, 1080	0	0	288	288	1863	1863	0	21	0	119	0	279	1.032	100.0
	1080	0	0	330	330	2131	2131	0	21	0	119	0	320	1.032	100.0

MOVEMENT NO. 1086, 1085, 1084

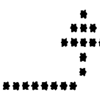
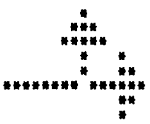
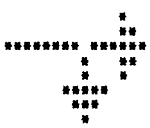
		FLOW (VEH/H) LEFT	THRU	RIGHT	TOTAL	SB TCU	S1 VEH	S2 VEH	G1 SEC	G2 SEC	R1 SEC	R2 SEC	CAP. VEH	DEG.OF SATN	RHO (%)
	1086	885	0	0	885	1867	1867	1867	51	21	25	43	960	.922	100.0
	1086, 1085	78	665	0	743	1790	1784	420	63	1	33	43	806	.922	100.0
	1085, 1084	0	80	385	465	1662	1641	0	43	0	97	0	504	.922	100.0

Fig. 3(d) - SIDRA-2 output for the example in Fig. 2: lane flows, effective timings, capacities, etc.

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                    LUK, LOWRIE AND SIMS - INTERSECTION 108 PARRAMATTA ( C=140 ) ...... * ARRB12 *            84/02/09.
SIGNAL TIMING DIAGRAM             CYCLE TIME = 140
---------------------

 DISPLAYED        PHASE 1          PHASE 2                 PHASE 3          PHASE 4
GREEN TIMES
             0                31                           76                     115               140
             1----------------1----------------------------1----------------------1-----------------1
             ...GGGGGGGGGGGGGGG.....GGGGGGGGGGGGGGGGGGGGGGGG....GGGGGGGGGGGGGGGGGGGG.....GGGGGGGGGGGG.
               5                 35                          80                    120

EFFECTIVE GREEN TIMES

MOV. 1080    1                1                            1                      1                 1
             G............................................................................GGGGGGGGGGGGG
              3                                                                     122

MOV. 1081    1                1                            1                      1                 1
             G................................................GGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGG
              3                                            82

MOV. 1082    1                1                            1                      1                 1
             ....GGGGGGGGGGGGGG...............................................................
                 7            34

MOV. 1083    1                1                            1                      1                 1
             ................................................GGGGGGGGGGGGGGGGGGGGGG.................
                                                           82                   118

MOV. 1084    1                1                            1                      1                 1
             ....................GGGGGGGGGGGGGGGGGGGGGGGGG.........................................
                                 37                        79

MOV. 1085    1                1                            1                      1                 1
             ....GGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGGG..........................................
                 7                                         79

MOV. 1086    1                1                            1                      1                 1
             GG..............GGGGGGGGGGGGGGGGGGGGGGGGGGGGGG...........................GGGGGGGGGGGGG
              3              28                            79                    122

             1-------1--------1--------1--------1--------1--------1--------1--------1--------1--------1--------1†
             0      14       28       42       56       70       84       98      112      126      140

                                              T I M E  (S)
```

Fig. 3(e) - SIDRA-2 output for the example in Fig. 2: phase times and effective times for movements

messages has been included for the benefit of the user, input and output formats and several aspects of the traffic model have been improved. Important model improvements have been discussed in this paper.

24. Extensive testing of SIDRA-2 has been carried out using over 250 data sets which range from simple hypothetical cases to complicated real-life problems, including the two workshop data sets. Average execution time per data set for the complicated cases is about three seconds of cpu time on ARRB CYBER 815 computer. The program is written in standard FORTRAN IV, and consists of about 40 subroutines with about 9000 executable lines. At the time of writing of this paper, public release of SIDRA-2 with the publication of a user guide was planned for August 1984. Preparation for the development of a microprocessor version of the program was also underway.

CONCLUSION

25. This paper has outlined the main features of SIDRA-2 and described the new method of calculating capacities and operating characteristics on a lane-by-lane basis. The new methods of SIDRA-2, including the lane interaction and opposed turn methods, will be described in more detail in the technical documentation of the program. The differences between SIDRA-2 methods and the traditional methods of signal design will be discussed in more detail in other publications.

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R. Akcelik

Rahmi Akcelik studied at the Istanbul Technical University for five years and following a period as a lecturer at the Karadeniz Technical University, completed his Ph.D. at the Institute for Transport Studies at the University of Leeds in 1974. He arrived in Australia in 1975 to work with the National Capital Development Commission as a traffic engineer. During this period he published papers on route control, traffic assignment and simulation. Rahmi joined ARRB in 1979 and is now a Principal Research Scientist in the Road Users Work Area.