# ARCADY HEALTH WARNING: Account for Unequal Lane Usage or risk damaging the public purse!

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The ARCADY computer program was first released in 1981. Developed by the Transport Research Laboratory, the program predicts capacities queues and delays on roundabout approaches from user specified geometric and origin/destination data. The latest release, Visual ARCADY/4, was released in October 1996. The program development can be studied by acquiring and reading references 1 to 10.

Over the years much development work has been carried out with many new features added to the program, for example, geometric delay, formulae for grade-separated entry arms, pedestrian crossings on approaches, accident rate and type predictions and, most recently, the addition of a more user friendly data entry module. However, in the intervening twenty six years, the 'heart' of the ARCADY model has remained essentially unchanged, i.e. the use of an empirical formula to derive, using geometric and traffic demand input data, the entry capacity of each arm as a function of the circulating flow across the arm entry.

This model is well proven. However, of itself, it can take no account of either unused or unequally used lanes or flared sections on the entry approaches ( see Photographs 1.1 and 1.2). ARCADY is in fact completely 'blind' to such occurrences, and as a consequence may produce hopelessly over-optimistic predictions. In the case of unspotted erroneous Traffic Impact Assessment (TIA) submissions, this can lead to ( and probably already has) the construction of inadequate designs that have to be 'improved' and/or replaced at a later date, often at a Highway Authority's considerable expense!

Following the author's public voicing of these concerns (Cornwall County Council presentation, " Arcady and Lane Usage - Time for an Update? ", ICE SW Association Transportation Engineering Group, Bristol, 5th December 1996), the Transport Research Laboratory (TRL) have agreed to place a warning in their new release, Visual ARCADY/4 documentation. They have also invited the author to submit a report illustrating the problem and any proposed solution methodology, this for their consideration and possible inclusion in future ARCADY User Manual documentation.

This paper basically constitutes such a report. Examples illustrating the inability of ARCADY to directly account for non or unequal lane usage are given together with details of the authors modelling methodology aimed at achieving more 'realistic' queue and delay predictions.

## 1. INTRODUCTION

The purpose of this paper is to:-

- Alert ARCADY Users to the problem of ARCADY's inability to directly account for non or unequal lane usage on roundabout approaches;
- Illustrate the problem with a simple example;
- Present methods adopted by the author to overcome the problem and achieve 'more realistic' ARCADY predictions;
- Present ideas as to how ARCADY and/or competitor programs need to develop from here.

As a prelude to the above, section 2 reminds readers of the basic methodology employed in the ARCADY computer program.

## 2. ARCADY BASICS

The ARCADY computer program calculates capacities queues and delays, arm by arm, as demand flows vary over a peak period. These derivations are made from a knowledge of the traffic origin/destination data, and the geometry of the roundabout.

The 'entry capacity' (i.e. the maximum amount of traffic that can join the roundabout from a steady queue on the roundabout is given by the 'Intercept/Slope' or 'Entry Capacity ($Q_e$) /Circulating Flow ($Q_c$)' relationship:-

$Q_e = F - f_c Q_c$ pcu/hr .................... equation 1 (Figure 2.1)

F and $f_c$ are the 'Intercept' and 'Slope' of the relationship and depend on the geometry of the junction and of the entry as follows:-

$F = 303 x_2 k$
$f_c = 0.210 t_D k (1 + 0.2 x_2)$
$k = 1 - 0.00347 (Phi - 30) - 0.978 (1/r - 0.05)$
$t_D = 1 + 0.5 / \{1 + \exp[(D-60)/10]\}$
$x_2 = v + ([e-v] / [1 + 2S])$
$S = 1.6 ([e-v] / l')$

v, e, l', r, D and Phi are user specified geometric parameters for the roundabout and for each approach (Figure 2.2).

v is the approach road half-width(m)
e is the entry width (m)
Phi is the entry angle (degrees)
r is the entry radius (m)
l' is the length of the flare (m)
D is the inscribed circle diameter (m)

The equations for F and $f_c$ above, were empirically derived and calibrated using extensive observations on the TRL test track [2] (1977), and on the public road [5] (1980). Equation 1 is for 'at-grade' roundabouts. For grade-separated roundabouts, equation 1 is modified to:-

$Q_e = 1.1 F - 1.4 f_c Q_c$ pcu/hr .................... equation 2

When the demand flow at an entry is less than the maximum entry capacity, the flow entering the roundabout is equal to the demand flow. An iterative procedure is adopted in ARCADY to 'balance' the entry and resulting 'circulating flows' on the gyratory. Queues and delays are subsequently derived using time-dependant queuing theory [4] from a knowledge of the demand flows and entry capacities.

In ARCADY, the accurate prediction of queues and delays depends entirely on obtaining reliable estimates of capacity. We are warned in the ARCADY/2 [8] Research Report and the ARCADY/3 Application Guide [9] that the empirical Intercept/Slope relationship is dependent on modelled geometric parameters of the roundabout being within the range of values used to calibrate the model and that the capacity formulae have a standard error of prediction of 15% of the entry capacity due to unexplained site-to-site variation.

However, nowhere are we warned, that in addition to such inaccuracies, modelling the full approach geometry when a significant surface area of that approach is road space not used by traffic, may produce seriously erroneous results.

The ARCADY program does however, incorporate a facility for correcting the Intercept value in the entry flow/circulating flow relationship. This is to allow for site-to-site variation.

The correction is obtained by observing entry versus circulating flows at a roundabout arm over a large number of short saturated time periods in the peak period and entering the average measurements as additional input to the program. The program uses this data to produce a correction (of intercept) to the capacity relationship for the arm in question. The subsequent queue and delay predictions for this arm will consequently be improved. This procedure is illustrated in Figure 2.3. Much use will be made of this facility in the 'solution methodology' proposed in this paper.

## 3. PROBLEMS AND SOLUTIONS

This section illustrates ARCADY's 'blindness' to the problem of non and/or unequal lane usage and provides details of modelling methodology adopted by the author to achieve more realistic queue and delay predictions. To apply this methodology, you will need to create a small spreadsheet program (Figure 3.0) that derives the Intercept F (i.e. maximum entry capacity) and slope $f_c$ for entered v,e,l',r,D and Phi values using equations 1 or 2.

Three cases are identified and dealt with. These are:-

- Case A: Non-usage of lane/s on a roundabout approach;
- Case B: Unequal usage of lanes on a roundabout approach; and
- Case C: Non and/or unequal usage of lanes and/or flared sections on a roundabout approaches.

### 3.1 Case A: Non-usage of lane/s on a roundabout

**The problem:** Consider the roundabout illustrated in Figure 3.1a. Each entry approach has two lanes and similar approach geometry. All lanes are clearly marked so that traffic distributes itself according to the lane indications. In Figure 3.1a, the origin-destination pattern of the approaching traffic is such that on each Arm, the approach lanes are <u>equally used.</u> ARCADY will have no problem with this. The input data file EX3_1A and relevant parts of the output for this example are given in Table 1.

However, consider this same roundabout with a different origin-destination flow pattern arriving on Arm C, i.e. a pattern whereby all approaching vehicles want to travel straight-ahead only (Figure 3.1b). Because of the lane markings ( and, let us also assume, only a single lane exit on Arm A ), all approaching traffic will use the nearside lane only on Arm C. The Arm C offside lane will be unused. ARCADY will be totally blind to this fact and this is evident from the run results given in Figure 3.1b and Table 2. ARCADY is programmed to assume that the whole of the modelled approach is available and used by traffic on Arm C and still assigns a two lane maximum entry capacity of 34.2 pcu/min for this arm. Over-optimistic predictions of queues and delays are the inevitable result.

**The Solution:** As mentioned earlier, ARCADY has a 'Local Capacity Correction' facility, intended to allow a correction of Intercept to the capacity relationship. Use can be made of this facility to more correctly model Arm C in example 3.1b. Arm C is essentially behaving as a single lane approach. Insert the geometry appropriate to this single lane, i.e., v=3m, e=3.65, l=10m, r=20m, D=40m Phi= 40, into your newly prepared spreadsheet (Figure 3.0). ARCADY predicts an Intercept of 17.247 and a Slope of 0.499 for this geometry. When modelled with the actual full two lane approach geometry, ARCADY gives Intercept and Slope values of 34.189 and 0.702, respectively (Tables 1 & 2).

The more appropriate Intercept value of 17.247 is achieved by applying an 'Intercept Correction value' given by 17.247 - 34.189 = -17, and using the original approach geometry. ( When originally addressing this non lane usage problem, I considered simply changing the modelled geometry for Arm C to that of the single approach lane. However, this would have applied a change in the Slope value from the original 0.702 to 0.499. Following discussion with TRL, the best advise at the time was to leave the slope unchanged. This decision was no doubt influenced by the fact that ARCADY is already programmed to assume the 'actual geometry' Slope value when deriving Intercept Correction factors from user-supplied (i.e. site measured) average $Q_e$ and $Q_c$ values).

The 'corrected' input data file EX3_1BC and relevant parts of the resulting output are given in Table 3. The Ratio of Flow to Capacity (RFC) value of 2.646 and queue of 588+ is closer to the answer one would expect than the earlier predictions of 0.867 and 6.1, respectively. ( Had the slope also been changed the resulting RFC and queue values would have been 2.008 and 453+, respectively).

<u>In summary</u>: ARCADY is 'blind' to lanes on the approach that are not used. Modellers must account for this by either not modelling the unused lane or by applying a derived 'Intercept Correction' value to the existing geometry. In deriving the Intercept Correction value, one can take a little licence with the geometry of the single lane usage, in that cars in a single lane with an unused adjacent lane feel more free to manoeuvre and thus may achieve a slightly higher entry rate into the roundabout. *( Please note, that when you are deriving a single lane intercept value, e must always be greater than or equal to v).* My own experience of on-site measurement is that single lane entry rates for no circulating traffic (i.e. Intercept values) vary from say 24 veh/min for a 3.5m wide single lane entry on the flat, to a minimum of about 17 veh/min for a narrow approach on a slight uphill gradient.

### 3.2 Case B: Unequal usage of lane/s on a roundabout approach

**The Problem:** Consider Arm A of the roundabout illustrated in Figure 3.2a. The two approach lanes are unequally used. ARCADY is 'blind' to this fact. If you enter the full approach geometry for this arm, ARCADY will produce an over optimistic result, i.e. predicted queues and delays on this approach will be too small.

**The Solution:** This problem may be overcome by modelling each of the approach lanes in a separate run as though it were the only lane on the approach from this Arm. However, this procedure will sometimes require re-allocated entry and exit flows at 'dummy' arms in order to maintain entry/circulating flow relationships around the gyratory. In this example two ARCADY runs are proposed as follows.

In Run 1 (Figure 3.2b), omit the nearside lane altogether, and model lane 2 of Arm A as though it were a single lane approach carrying the 600 offside lane vehicles. No 'dummy arms' are required as the controlling circulating flow past each entry remains unchanged.

In Run 2 (Figure 3.2c), omit the offside lane on Arm A, and model Arm A as though a single lane approach carrying the nearside 200 vehicles only. However, in addition, you will also need to introduce a 'dummy' arm immediately downstream, this to re-allocate the exiting 200 vehicles from Arm A, and re-allocate the entering 600 vehicles that previously entered on the offside lane on Arm A. In this way, the circulating flow past each entry is maintained and more accurate predictions of queues and delays for the nearside lane on Arm A is achieved.

There are many possible variations on this theme according to the origin/destination of traffic arriving unequally on multi-lane approaches. The example shown here serves to illustrate the thinking and methodology that should be applied to such situations. Indeed for this example, Run 2 is probably sufficient on it's own!

In Summary: Where approach lanes are unequally used, execute one or more ARCADY runs modelling the lanes individually, and making use of added dummy Arms and re-allocated entry and exit flows to protect the original entry/circulating flow relationships on the gyratory.

### 3.3 Case C: Non and/or unequal usage of flared sections on a roundabout approach.

**The Problem:** Consider the roundabout illustrated in Figure 3.3. This example is similar to one actually submitted by a Developer's Consultant for a 'proposed' new roundabout for the design year 2015. The modeller, unaware and unwarned of ARCADY's blindness to unequal use of lanes and/or flared sections on the roundabout approaches measured the geometric parameters off the 1/500 scale drawing and entered these, together with the origin / destination flow data into ARCADY. The submitted input data, file EX3_3, and relevant parts of the output so produced are given in Table 4. The modeller was no doubt pleased with predictions that declared this roundabout as operating comfortably within capacity up to the year 2015!

However, if we look at this example a little more closely wearing our 'checkers' hat. The supplied geometric input data, the exit geometry shown on the drawing and the supplied origin destination data should tell us that:-

Arm A is a single lane approach that flares to 2 lanes starting from about 50m back from the entry. However, since nearly all the traffic on this approach is turning right to Arm D, and Arm D is a single lane exit, most of the traffic (i.e. 821/844 = 97%) is likely to use the single lane approach and offside flare section only. Use of the nearside flare section will be minimal. ARCADY will be 'blind' to this fact, and therefore the user will have to account for this.

Solution: 821 vehicles use the offside flare section, 23 vehicles the nearside flare. Ignoring first of all the nearside flare usage, if Arm A was modelled as a single lane approach, with v=3.65, e=4, l'=25, r=20, D=75 and Phi= 9, ARCADY would derive an Intercept of 21.59. To account for usage of the nearside flare section, apply an '**Intercept Weighting Factor**' given by 844/821 = 1.028. This would take the Intercept for this approach to 21.59 x 1.028 = 22.19. To effect this, we would model the geometry as measured, but apply an Intercept Correction Value of 22.19-33.2= -11, to this Arm.

(Note: if this derived 'new Intercept' value is greater than the original Intercept using the measured approach geometry, {i.e. 32.2 in this case}, you would abandon these corrective measures and simply run ARCADY as normal. By adopting this general rule, corrective measures suggested in this report will never produce new Intercepts that are greater than those derived from the as measured geometric parameters).

Arm B is a single lane approach that flares into at least two, and possibly 3 lanes at the approach entry. However,the origin-destination flow data tells us that it is not unreasonable that traffic will distribute itself fairly evenly across the approach lanes, an assumption that is inherently incorporated in the ARCADY model. Arm C has too small a flow for us to worry about.

ARM D is a two lane approach flaring towards the approach entry. 88% of the approach traffic is turning left into a single exit lane on Arm A. These left-turners will be obliged to use the nearside lane only. Thus only the 202 straight-aheads and right-turners can sensibly use the offside lane on this approach. ARCADY is blind to this fact. The user must spot such situations and model to account for them. Since we have two full lanes on this approach rather than a single lane flaring into two, we could apply either the Intercept Weighting Factor method (solution (i)), or Case B methodology (solution (ii)).

Solution (i): 1526 vehicles use the nearside lane, 202 vehicles the offside lane. Ignoring first of all the offside lane usage, if Arm D was modelled as a single lane approach, with v=3.65, e=5.25, l'=28.5, r=20, D=75 and Phi= 11, ARCADY would derive an Intercept of 27. To account for usage of the offside lane, apply an 'Intercept Weighting Factor' given by 1728/1526 = 1.132. i.e. a more appropriate Intercept for this approach might be 27 x 1.132 = 30.56. Thus model the geometry as measured (i.e. Intercept will be 52), but apply an Intercept Correction Value of 30.56 - 52 = -21. The 'corrected' input data file using this approach (i.e. EX3_3C) and resulting output is shown in
Table 5.

Solution (ii): The methodology described for Case B is an alternative approach. i.e., we could introduce a dummy Arm E immediately downstream of Arm D (Figure 3.4). We would model only the 1526 vehicles entering on Arm D, but would re-allocate their exit to Arm E. The 202 vehicles previously on the Arm D offside lane would now be modelled as entering on the dummy Arm E. (Arms D and E would be modelled as single lane approaches). The 'corrected' input data file using this approach (i.e. EX3_3CC) and resulting output is shown in Table 6.

When correction is made for actual lane usage on Arms A and D, the answer is somewhat different and indeed much more what you would expect looking at the input information, i.e. a maximum RFC value and queue of 1.255 and 214 vehicles, respectively on Arm D if solution (i) is used for that arm (see Table 5), or 1.242 and 182, respectively, if solution (ii) is used for Arm D (see Table 6). The two methodologies produce slightly different answers. However, the important point here is that they both produce more realistic predictions!

Had the modelling errors in this submission not been spotted by an experienced TIA checker, and had this roundabout been constructed as shown, it would have proved woefully inadequate by the year 2015!

In Summary: Where flared sections of a roundabout are unequally used, a proposed modelling methodology is to first derive an appropriate Intercept for the main lane modelled as a single lane approach ( remembering that e must be greater than or equal to v), then apply an Intercept Weighting Factor to account for the 'under-used' flare sections.

If any newly calculated Intercept for an approach is larger than that which ARCADY would have calculated using the original measured geometry only, then abandon any corrections for this approach. Derived new Intercepts that are larger than those derived by ARCADY using the actual measured approach geometry, are an indication that 'unequal lane usage' is borderline and that no corrections are required.

## 4. THE WAY FORWARD - SOME PROPOSALS

This paper highlights a serious short-coming of the current ARCADY program when non or unequal lane usage of roundabout approaches is in evidence. Examples have been given that illustrate the problem and proposed solution methodology provided. However, such methodology is intended only as a 'holding exercise ' and/or 'warning with some guidance', until either ARCADY is updated or a new program produced. Some suggested proposals as to the way forward are:-

In the short term

- that the Department of Transport and/or the newly privatised Transport Research Laboratory be persuaded to post a warning and some guidance to all licensed ARCADY users, regarding non and/or unequal lane usage;

- that users of software incorporating the direct ARCADY model ( i.e. RODEL, COBA ) and those using modelling suites that align their roundabout modelling indirectly to the ARCADY Intercept/Slope outputs ( e.g. SATURN, TRIPS, ) take note and consider whether they too need to proceed cautiously when modelling roundabout junctions;

if you are an originator and/or checker of ARCADY models, further recommendations are:-

- At Existing Sites - to go and watch driver behaviour / lane usage in the peak periods prior to setting up and/or checking ARCADY models. Arguments that you have no time, or that site visiting is too expensive do not stand when weighed against the cost of proposing or passing inadequate designs;

- At New or Proposed Future Sites - to superimpose the peak hour traffic flows on your design, and decide in advance of modelling, how you intend this traffic to use the lanes on your approaches. Be sure to state your lane usage assumptions on preliminary drawings and TIA submissions. Ensure also, that any intended lane markings are applied at implementation.

In the longer term

- that either the Department of Transport be persuaded to provide adequate funding for appropriate further research and subsequent amendment to the current ARCADY model or that a budding entrepreneur take up the challenge to provide a new 'by lane entry' model rather than the current, and possibly now outdated, 'by approach entry' model!

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**Table 1.** Case A - equal lane usage on all entries

**input**:-

```
FILE EX3_1A: EQUAL LANE USAGE ON ALL ENTRIES
 &PARAM NARMS=3,START= 745,FINISH= 915,INTERV= 15 &END
 &OPTION  TPENT=T,GSAME=T,ODTAB=T  &END
A
B
C
*        V        E        L        R        D       PHI
     6.000    7.500   10.000   20.000   40.000   40.000
* TURNING COUNTS (VEHICLES) FOR PEAK HOUR
      0.00   600.00   600.00
    700.00     0.00   700.00
    600.00   600.00     0.00
* PERCENTAGES OF HEAVY VEHICLES
      0.00     0.00     0.00
```

**output**:-

```
GEOMETRIC DATA
  ------------------------------------------------------------------------------------------------------------------
 I ARM   I   V (M)   I    E (M)   I    L (M)   I    R (M)   I   D (M)   I   PHI (DEG)  I  SLOPE  I INTERCEPT (PCU/MIN) I
 ------------------------------------------------------------------------------------------------------------------
 I ARM A I    6.00   I     7.50   I    10.00   I    20.00   I   40.00   I     40.0     I  0.702  I       34.189        I
 I ARM B I    6.00   I     7.50   I    10.00   I    20.00   I   40.00   I     40.0     I  0.702  I       34.189        I
 I ARM C I    6.00   I     7.50   I    10.00   I    20.00   I   40.00   I     40.0     I  0.702  I       34.189        I
 ------------------------------------------------------------------------------------------------------------------
 QUEUE AND DELAY INFORMATION FOR EACH 15 MIN TIME SEGMENT
 -----------------------------------------------------------------------------------------------
 I  TIME       DEMAND  CAPACITY  DEMAND/    PEDESTRIAN  START   END        DELAY      GEOMETRIC DELAYI
 I          (VEH/MIN) (VEH/MIN) CAPACITY       FLOW     QUEUE  QUEUE    (VEH.MIN/       (VEH.MIN/   I
 I                                (RFC)     (PEDS/MIN) (VEHS)  (VEHS)  TIME SEGMENT)   TIME SEGMENT) I
 I 08.30-08.45                                                                                       I
 I ARM A       21.94     26.51   0.828                    4.4     4.6       67.8                     I
 I ARM B       25.59     26.50   0.966                   13.5    16.9      231.0                     I
 I ARM C       21.94     25.29   0.867                    5.6     6.1       87.9                     I
 -----------------------------------------------------------------------------------------------
```

**Table 2.** Case A: Non-usage of lane/s on a roundabout approach

**input:-**

```
FILE EX3_1B: EFFECT OF NON LANE USAGE ON ARM C
 &PARAM NARMS=3,START= 745,FINISH= 915,INTERV= 15 &END
 &OPTION  TPENT=T,GSAME=T,ODTAB=T  &END
A
B
C
*        V        E        L        R        D       PHI
     6.000    7.500   10.000   20.000   40.000   40.000
* TURNING COUNTS (VEHICLES) FOR PEAK HOUR
      0.00   600.00   600.00
    700.00     0.00   700.00
   1200.00   000.00     0.00
* PERCENTAGES OF HEAVY VEHICLES
      0.00     0.00     0.00
```

**output:-**

```
 GEOMETRIC DATA
 ------------------------------------------------------------------------------------------------------------------
 I ARM   I   V (M)   I    E (M)   I    L (M)   I    R (M)   I   D (M)   I   PHI (DEG)  I  SLOPE  I INTERCEPT (PCU/MIN) I
 ------------------------------------------------------------------------------------------------------------------
 I ARM A I    6.00   I     7.50   I    10.00   I    20.00   I   40.00   I     40.0     I  0.702  I       34.189        I
 I ARM B I    6.00   I     7.50   I    10.00   I    20.00   I   40.00   I     40.0     I  0.702  I       34.189        I
 I ARM C I    6.00   I     7.50   I    10.00   I    20.00   I   40.00   I     40.0     I  0.702  I       34.189        I
 ------------------------------------------------------------------------------------------------------------------
         QUEUE AND DELAY INFORMATION FOR EACH 15 MIN TIME SEGMENT
 -----------------------------------------------------------------------------------------------
 I  TIME       DEMAND  CAPACITY  DEMAND/    PEDESTRIAN  START   END       DELAY      GEOMETRIC DELAYI
 I          (VEH/MIN) (VEH/MIN) CAPACITY      FLOW     QUEUE  QUEUE    (VEH.MIN/      (VEH.MIN/   I
 I                                (RFC)    (PEDS/MIN) (VEHS)  (VEHS)  TIME SEGMENT)  TIME SEGMENT) I
 I 08.30-08.45                                                                                    I
 I ARM A      21.94     34.19   0.642                   1.8     1.8       26.6                    I
 I ARM B      25.59     26.49   0.966                  13.7    17.1      233.6                    I
 I ARM C      21.94     25.29   0.867                   5.5     6.1       87.9                    I
 -----------------------------------------------------------------------------------------------
```

**Table 3.** Case A: Correction for Non-usage of lane/s on a roundabout approach

**input:-**

```
FILE EX3_1BC: APPLY INTERCEPT CORRECTION -17 ON ARM C
 &PARAM NARMS=3,START= 745,FINISH= 915,INTERV= 15 &END
 &OPTION  TPENT=T,GSAME=T,INTCOR=T,ODTAB=T  &END
A
B
C
*       V        E         L         R         D       PHI
     6.000    7.500   10.000    20.000    40.000    40.000
*INTERCEPT CORRECTION (FOR SITE SPECIFIC DATA)
     0.000    0.000   -17.000
* TURNING COUNTS (VEHICLES) FOR PEAK HOUR
      0.00   600.00   600.00
    700.00     0.00   700.00
   1200.00     0.00     0.00
* PERCENTAGES OF HEAVY VEHICLES
      0.00     0.00     0.00
```

**output:-**

```
 GEOMETRIC DATA
  ----------------------------------------------------------------------------------------------------------------------
 I ARM   I   V (M)    I    E (M)    I    L (M)    I    R (M)    I    D (M)    I   PHI (DEG)   I  SLOPE  I INTERCEPT (PCU/MIN) I
 ----------------------------------------------------------------------------------------------------------------------
 I ARM A I    6.00    I     7.50    I    10.00    I    20.00    I    40.00    I     40.0      I  0.702  I       34.189        I
 I ARM B I    6.00    I     7.50    I    10.00    I    20.00    I    40.00    I     40.0      I  0.702  I       34.189        I
 I ARM C I    6.00    I     7.50    I    10.00    I    20.00    I    40.00    I     40.0      I  0.702  I       17.189    *   I
 ----------------------------------------------------------------------------------------------------------------------
 ONE OR MORE INTERCEPT VALUES (FLAGGED * IN THE TABLE) HAS BEEN ADJUSTED
 ACCORDING TO LOCAL VALUES INPUT FROM A PREVIOUS RUN AND LISTED BELOW - note * denotes Intercept Corection applied
  -------------------------------
 I       I    ADJUSTMENT TO    I
 I       I INTERCEPT (PCU/MIN) I
 -------------------------------
 I ARM C I        -17.000      I
 -------------------------------
           QUEUE AND DELAY INFORMATION FOR EACH 15 MIN TIME SEGMENT
 -----------------------------------------------------------------------------------------------
 I  TIME       DEMAND  CAPACITY  DEMAND/   PEDESTRIAN  START   END       DELAY     GEOMETRIC DELAYI
 I          (VEH/MIN) (VEH/MIN) CAPACITY     FLOW     QUEUE  QUEUE    (VEH.MIN/      (VEH.MIN/   I
 I                                (RFC)    (PEDS/MIN) (VEHS) (VEHS)  TIME SEGMENT)  TIME SEGMENT) I
 I 08.30-08.45                                                                                   I
 I ARM A      21.94     34.19   0.642                   1.8    1.8       26.6                     I
 I ARM B      25.59     26.49   0.966                  13.7   17.1      233.6                     I
 I ARM C      21.94      8.29   2.646                 383.7  588.4     7291.0                     I
 I                                                                                                I
 -----------------------------------------------------------------------------------------------
```

**Table 4.** Case C: Submitted TIA example that failed to notice and account for unequal usage of lanes and flared sections on roundabout approaches A and D

**Input:-**

```
FILE EX3_3: UNEQUAL LANE/FLARE USAGE ON APPROACHES - example 3

 &PARAM NARMS=4,START= 745,FINISH= 915,INTERV= 15 &END
 &OPTION  HVDEF=T,TPENT=T,INTCOR=T,ODTAB=T  &END
ARM A
ARM B
ARM C
ARM D
*        V         E         L         R         D       PHI
     3.650     7.300    25.000    20.000    75.000     9.000
     3.650     9.000    50.000    20.000    75.000     9.000
     3.650     4.550    23.000    25.000    75.000     3.500
     7.300    10.500    28.500    20.000    75.000    11.000
*INTERCEPT CORRECTION (FOR SITE SPECIFIC DATA)
     0.000     0.000     0.000     0.000
* TURNING COUNTS (VEHICLES) FOR PEAK HOUR
      0.00     10.00     13.00    821.00
    223.00      0.00      0.00    188.00
      5.00      0.00      0.00      2.00
   1526.00    201.00      1.00      0.00
```

**Output:-**

```
 GEOMETRIC DATA
   ----------------------------------------------------------------------------------------------------------------
 I ARM   I   V (M)   I    E (M)   I    L (M)   I    R (M)   I   D (M)   I   PHI (DEG)  I  SLOPE  I INTERCEPT (PCU/MIN) I
 ------------------------------------------------------------------------------------------------------------------
 I ARM A I    3.65   I     7.30   I    25.00   I    20.00   I   75.00   I      9.0     I  0.548  I       33.254        I
 I ARM B I    3.65   I     9.00   I    50.00   I    20.00   I   75.00   I      9.0     I  0.621  I       41.369        I
 I ARM C I    3.65   I     4.55   I    23.00   I    25.00   I   75.00   I      3.5     I  0.477  I       24.758        I
 I ARM D I    7.30   I    10.50   I    28.50   I    20.00   I   75.00   I     11.0     I  0.716  I       51.968        I
 ------------------------------------------------------------------------------------------------------------------
 QUEUE AND DELAY INFORMATION FOR EACH 15 MIN TIME SEGMENT
-----------------------------------------------------------------------------------------------
 I  TIME       DEMAND   CAPACITY  DEMAND/    PEDESTRIAN  START   END       DELAY     GEOMETRIC DELAYI
 I           (VEH/MIN) (VEH/MIN) CAPACITY      FLOW      QUEUE  QUEUE    (VEH.MIN/       (VEH.MIN/   I
 I                                 (RFC)    (PEDS/MIN)  (VEHS)  (VEHS)  TIME SEGMENT)  TIME SEGMENT) I
 I 08.30-08.45                                                                                      I
 I ARM A       15.43      28.21   0.547                   1.2     1.2       18.0                    I
 I ARM B        7.51      28.12   0.267                   0.4     0.4        5.4                    I
 I ARM C        0.13      11.76   0.011                   0.0     0.0        0.2                    I
 I ARM D       31.59      44.26   0.714                   2.4     2.5       36.9                    I
 -------------------------------------------------------------------------------------------------
```

**Table 5.** Case C: Corrections applied to submitted TIA example that now take account for unequal usage of lanes and flared sections on roundabout approaches A and D

**input:-**

```
FILE EX3_3C: UNEQUALLY USED LANES/FLARES  - example 3 corrected
 &PARAM NARMS=4,START= 745,FINISH= 915,INTERV= 15 &END
 &OPTION  HVDEF=T,TPENT=T,INTCOR=T,ODTAB=T  &END
ARM A
ARM B
ARM C
ARM D
*        V         E         L         R         D       PHI
     3.650     7.300    25.000    20.000    75.000     9.000
     3.650     9.000    50.000    20.000    75.000     9.000
     3.650     4.550    23.000    25.000    75.000     3.500
     7.300    10.500    28.500    20.000    75.000    11.000
*INTERCEPT CORRECTION (FOR SITE SPECIFIC DATA)
   -11.000     0.000     0.000   -21.000
* TURNING COUNTS (VEHICLES) FOR PEAK HOUR
      0.00     10.00     13.00    821.00
    223.00      0.00      0.00    188.00
      5.00      0.00      0.00      2.00
   1526.00    201.00      1.00      0.00
```

**Output:-**

```
 GEOMETRIC DATA
  -----------------------------------------------------------------------------------------------------------------------
 I ARM   I  V (M)   I    E (M)   I    L (M)   I    R (M)   I   D (M)   I   PHI (DEG)  I  SLOPE  I INTERCEPT (PCU/MIN)  I
 ----------------------------------------------------------------------------------------------------------------------
 I ARM A I    3.65  I     7.30   I    25.00   I    20.00   I   75.00   I      9.0     I  0.548  I        22.254    *    I
 I ARM B I    3.65  I     9.00   I    50.00   I    20.00   I   75.00   I      9.0     I  0.621  I        41.369         I
 I ARM C I    3.65  I     4.55   I    23.00   I    25.00   I   75.00   I      3.5     I  0.477  I        24.758         I
 I ARM D I    7.30  I    10.50   I    28.50   I    20.00   I   75.00   I     11.0     I  0.716  I        30.968    *    I
 ----------------------------------------------------------------------------------------------------------------------
 ONE OR MORE INTERCEPT VALUES (FLAGGED * IN THE TABLE) HAS BEEN ADJUSTED
 ACCORDING TO LOCAL VALUES INPUT FROM A PREVIOUS RUN AND LISTED BELOW -
  -------------------------------
 I       I    ADJUSTMENT TO    I
 I       I INTERCEPT (PCU/MIN) I
 -------------------------------
 I ARM A I       -11.000       I
 I ARM D I       -21.000       I
 -------------------------------
 QUEUE AND DELAY INFORMATION FOR EACH 15 MIN TIME SEGMENT
 -------------------------------------------------------------------------------------------------
 I  TIME      DEMAND  CAPACITY  DEMAND/   PEDESTRIAN  START   END       DELAY     GEOMETRIC DELAYI
 I         (VEH/MIN) (VEH/MIN) CAPACITY      FLOW     QUEUE  QUEUE    (VEH.MIN/      (VEH.MIN/   I
 I                               (RFC)    (PEDS/MIN) (VEHS) (VEHS)  TIME SEGMENT)  TIME SEGMENT) I
 I 08.30-08.45                                                                                   I
 I ARM A      15.43     18.62   0.829                   4.4    4.6       67.3                    I
 I ARM B       7.51     28.13   0.267                   0.4    0.4        5.4                    I
 I ARM C       0.13     11.77   0.011                   0.0    0.0        0.2                    I
 I ARM D      31.59     25.17   1.255                 117.2  213.6     2481.3                    I
 I                                                                                               I
 -------------------------------------------------------------------------------------------------
```

**Table 6.** Case C:  As Table 5 but applying Case B methodology to Arm D

```
input:-

FILE EX3_3CC: AS EX3_3C, BUT CASE B METHODOLOGY FOR ARM D
 &PARAM NARMS=5,START= 745,FINISH= 915,INTERV= 15 &END
 &OPTION  HVDEF=T,TPENT=T,INTCOR=T,ODTAB=T  &END
A
B
C
D
E = Dummy Arm
*        V         E          L          R          D        PHI
     3.650     7.300    25.000    20.000    75.000     9.000
     3.650     9.000    50.000    20.000    75.000     9.000
     3.650     4.550    23.000    25.000    75.000     3.500
     3.650     5.250    28.500    20.000    75.000    11.000
     3.650     5.250    28.500    20.000    75.000    11.000
*INTERCEPT CORRECTION (FOR SITE SPECIFIC DATA)
   -11.000     0.000     0.000     0.000     0.000
* TURNING COUNTS (VEHICLES) FOR PEAK HOUR
      0.00     10.00     13.00    821.00      0.00
    223.00      0.00      0.00    188.00      0.00
      5.00      0.00      0.00      2.00      0.00
      0.00      0.00      0.00      0.00   1526.00
      0.00    201.00      1.00      0.00      0.00

 GEOMETRIC DATA
 ---------------------------------------------------------------------------------------------------------------------------------
 I ARM   I   V (M)   I    E (M)   I    L (M)   I    R (M)   I   D (M)   I   PHI (DEG)  I  SLOPE  I INTERCEPT (PCU/MIN) I
 ----------------------------------------------------------------------------------------------------------------------
 I ARM A I    3.65   I     7.30   I    25.00   I    20.00   I   75.00   I      9.0     I  0.548  I       22.254    *   I
 I ARM B I    3.65   I     9.00   I    50.00   I    20.00   I   75.00   I      9.0     I  0.621  I       41.369        I
 I ARM C I    3.65   I     4.55   I    23.00   I    25.00   I   75.00   I      3.5     I  0.477  I       24.758        I
 I ARM D I    3.65   I     5.25   I    28.50   I    20.00   I   75.00   I     11.0     I  0.489  I       26.949        I
 I ARM E I    3.65   I     5.25   I    28.50   I    20.00   I   75.00   I     11.0     I  0.489  I       26.949        I
 ----------------------------------------------------------------------------------------------------------------------
 ONE OR MORE INTERCEPT VALUES (FLAGGED * IN THE TABLE) HAS BEEN ADJUSTED
 ACCORDING TO LOCAL VALUES INPUT FROM A PREVIOUS RUN AND LISTED BELOW -
 -------------------------------
 I       I    ADJUSTMENT TO    I
 I       I INTERCEPT (PCU/MIN) I
 -------------------------------
 I ARM A I        -11.000      I
 -------------------------------
 QUEUE AND DELAY INFORMATION FOR EACH 15 MIN TIME SEGMENT
 -------------------------------------------------------------------------------------------------
 I  TIME      DEMAND  CAPACITY  DEMAND/   PEDESTRIAN  START   END       DELAY     GEOMETRIC DELAYI
 I          (VEH/MIN) (VEH/MIN) CAPACITY     FLOW     QUEUE  QUEUE    (VEH.MIN/      (VEH.MIN/   I
 I                               (RFC)    (PEDS/MIN) (VEHS) (VEHS)  TIME SEGMENT)  TIME SEGMENT) I
 I 08.30-08.45                                                                                   I
 I ARM A       15.43     18.21   0.847                  4.9    5.2       75.9                    I
 I ARM B        7.51     28.14   0.267                  0.4    0.4        5.4                    I
 I ARM C        0.13     11.77   0.011                  0.0    0.0        0.2                    I
 I ARM D       27.90     22.46   1.242                100.4  182.0     2117.7                    I
 I ARM E        3.69     22.46   0.164                  0.2    0.2        2.9                    I
 I                                                                                               I
 -------------------------------------------------------------------------------------------------
```

*Photograph 1.1. Origin-Destination pattern of this pm peak traffic is such that the near-side flare section is virtually unused. ARCADY is 'blind' to this fact*


*Photograph 1.2. This two-lane approach flares into three lanes at the entry no doubt giving better ARCADY capacity predictions. But traffic is not easily , comfortably or even safely able to use the middle section and doesn't!*

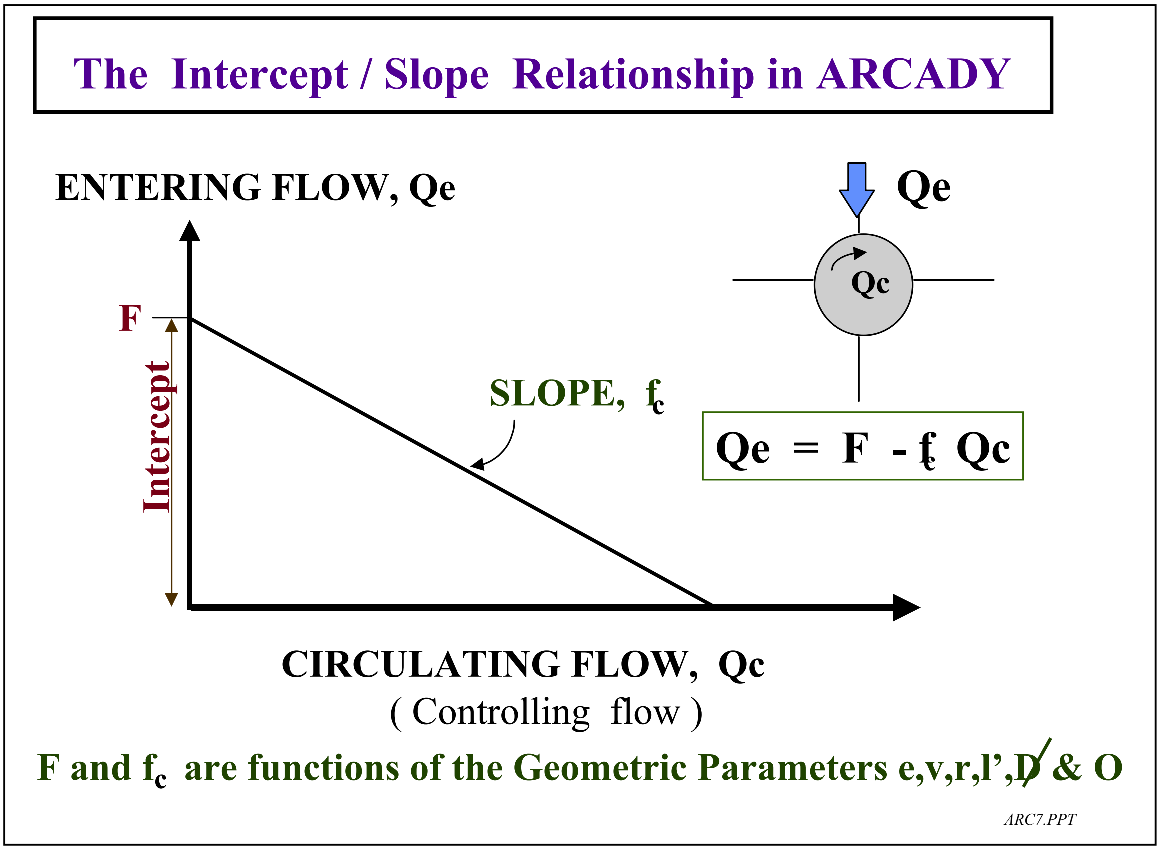



Figure 2.1 The Intercept / Slope Relationship in ARCADY

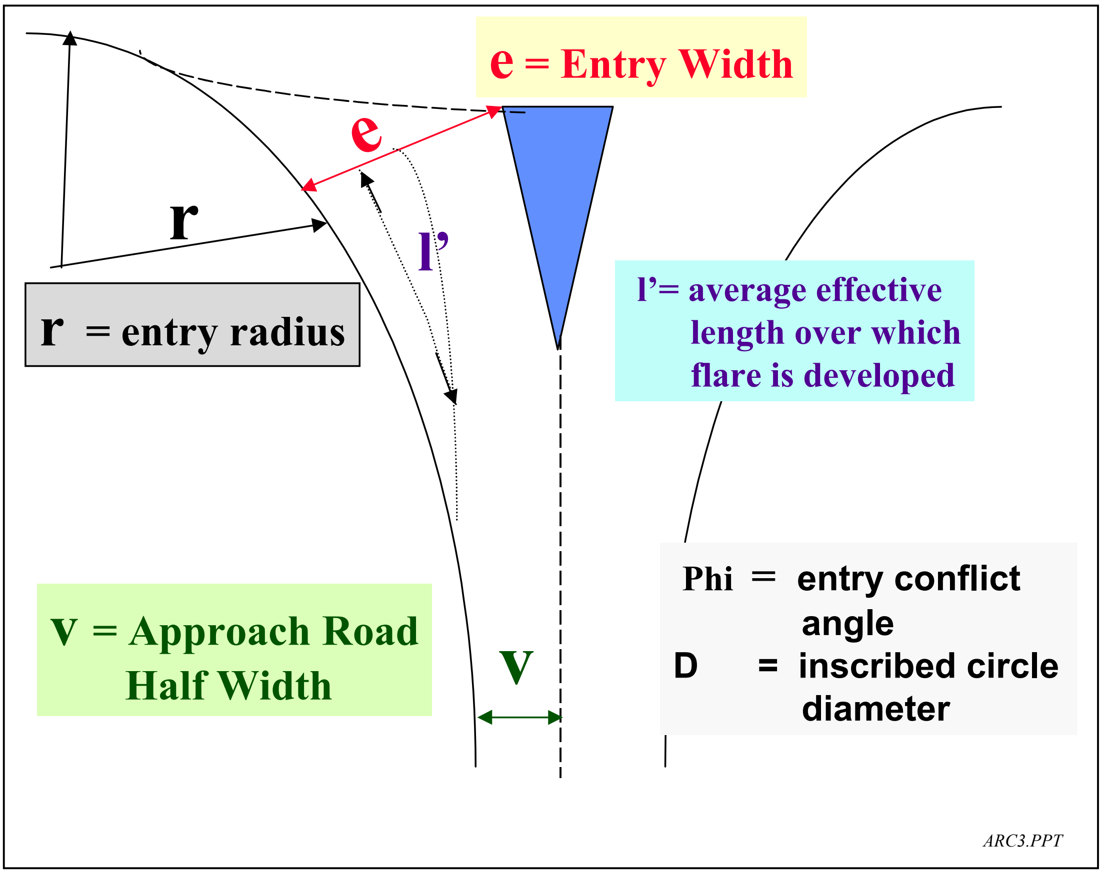



Figure 2.2 User specified geometric parameters for the roundabout and roundabout approaches

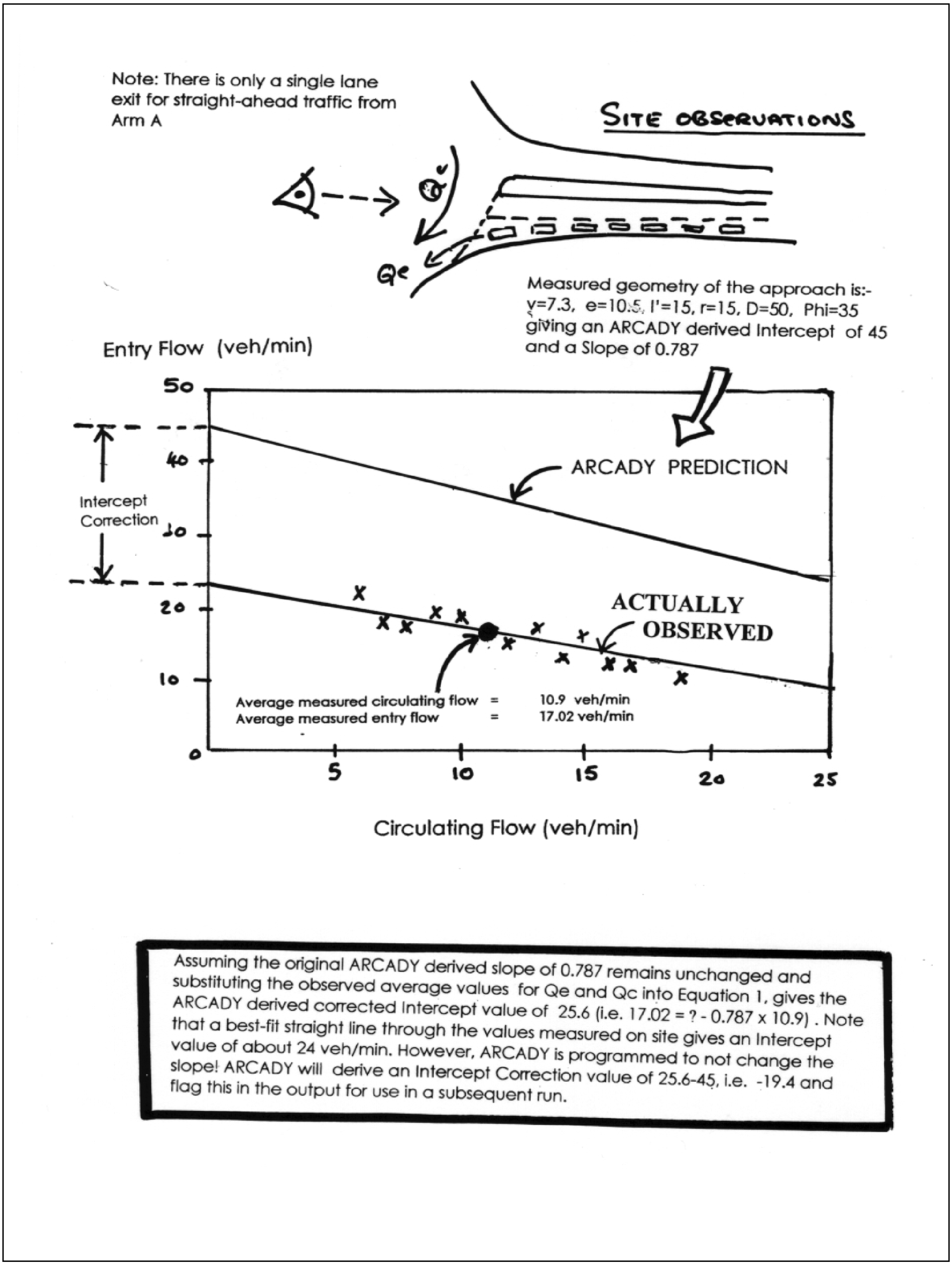



Figure 2.3 Illustration of the 'Intercept Correction' Facility in ARCADY

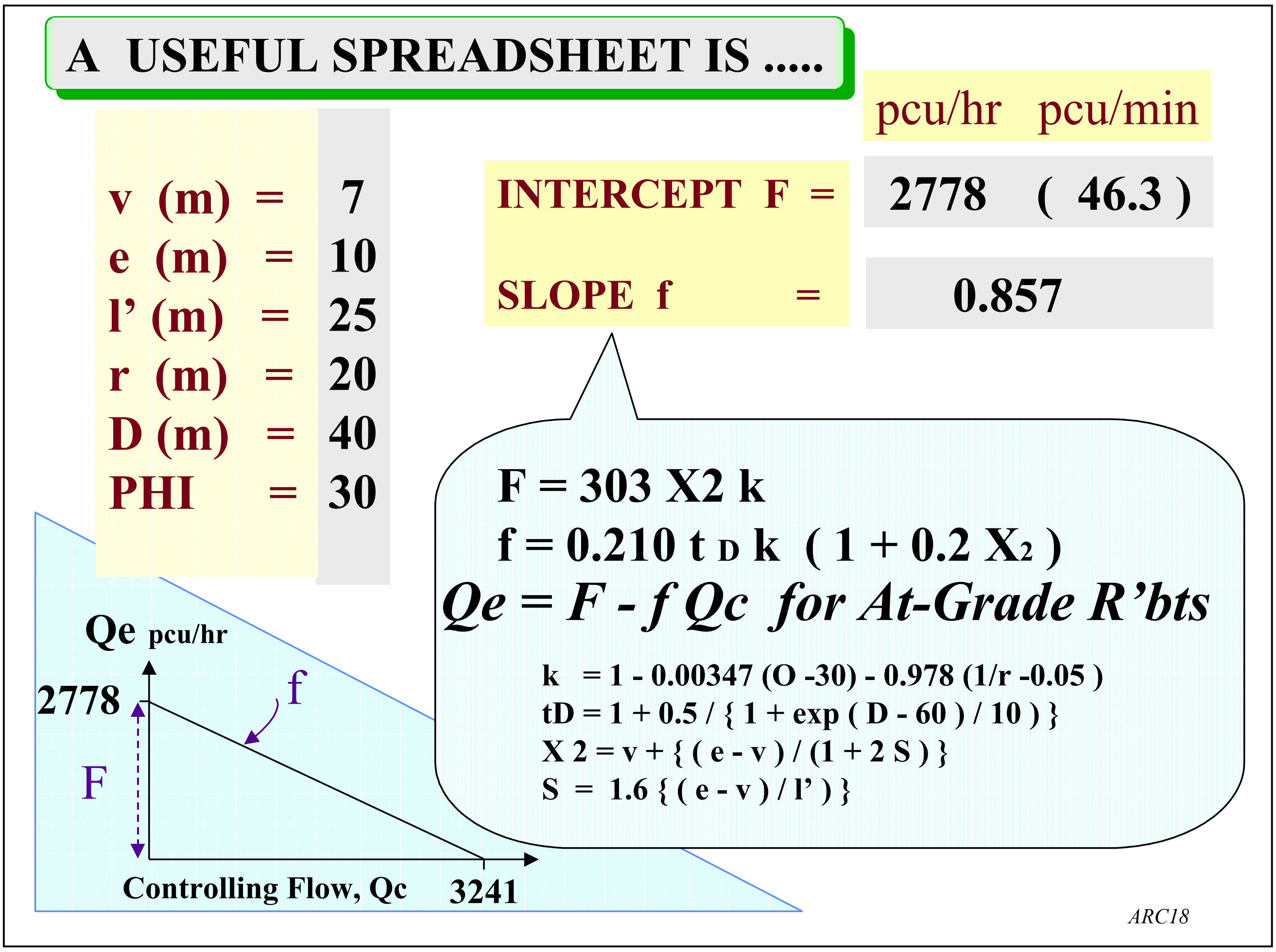



Figure 3.0 A useful spreadsheet for applying proposed solution methodology

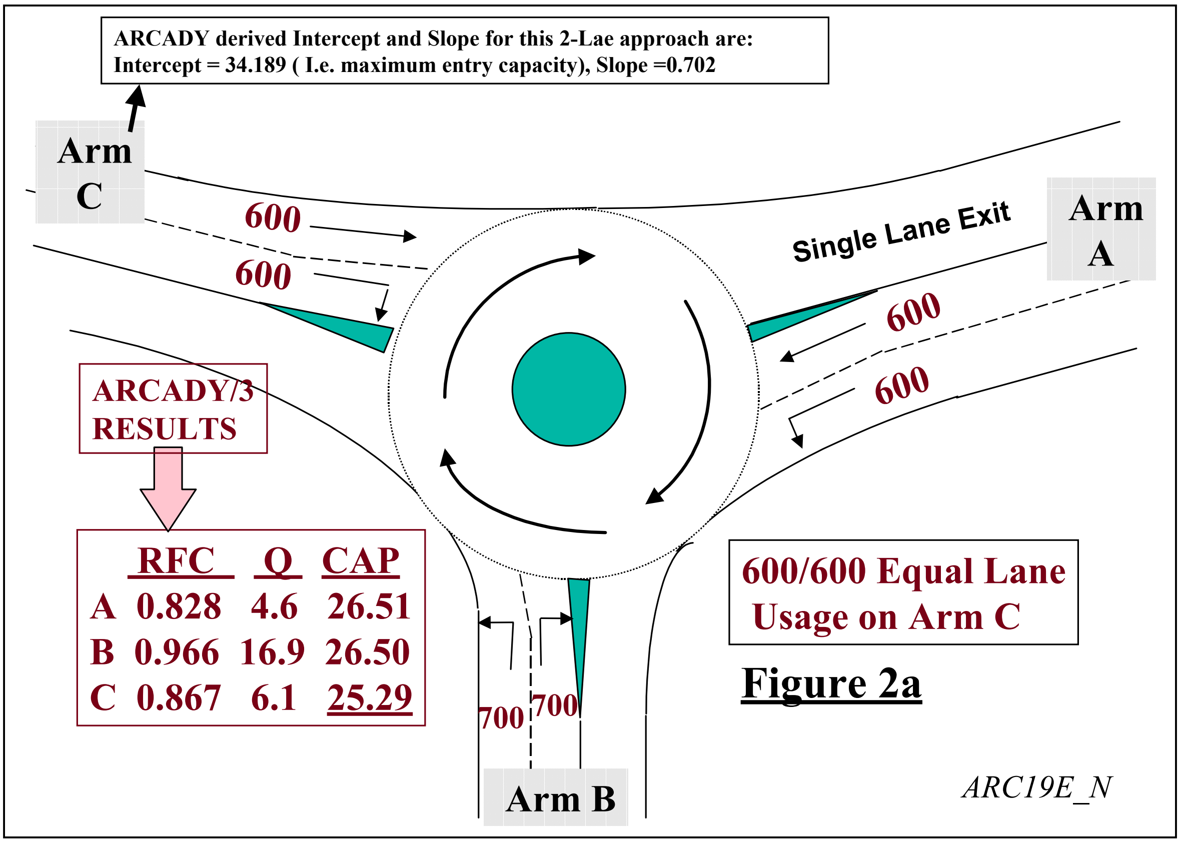



Figure 3.1a Example illustrating equal lane usage on a roundabout approach

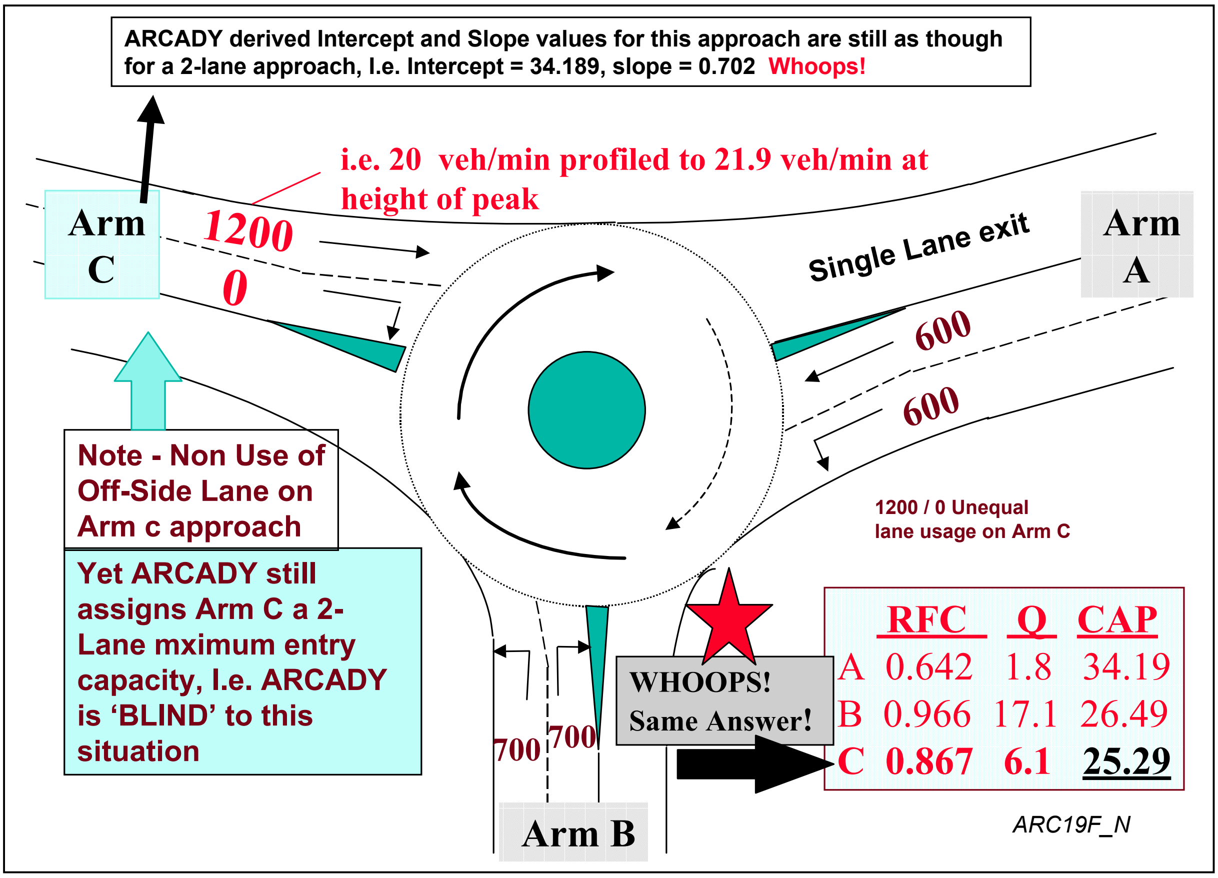



Figure 3.1b Case A: Example illustrating non-lane usage on a roundabout approach

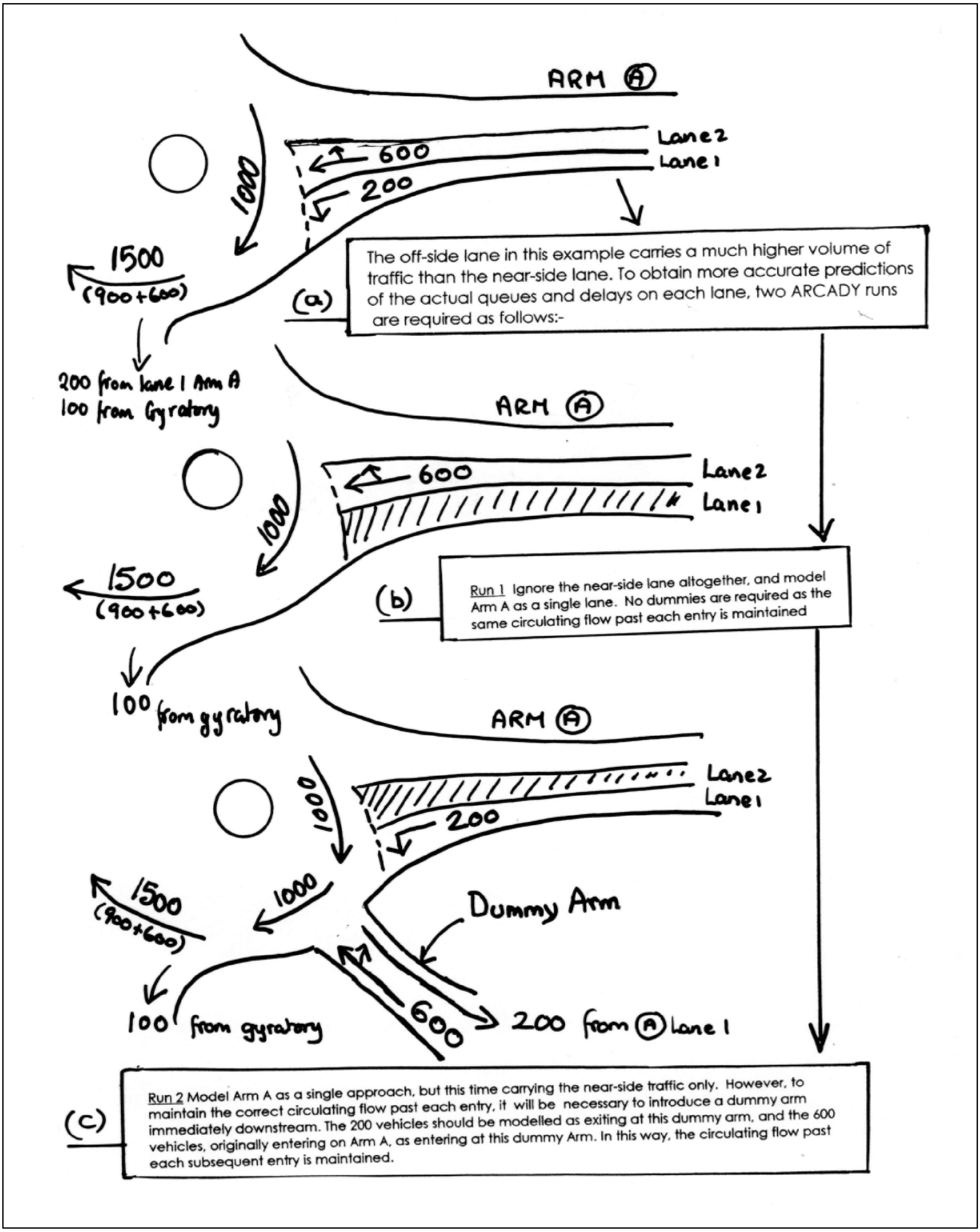



Figure 3.2 Case B – Example illustrating unequal usage of full lanes on a roundabout approach

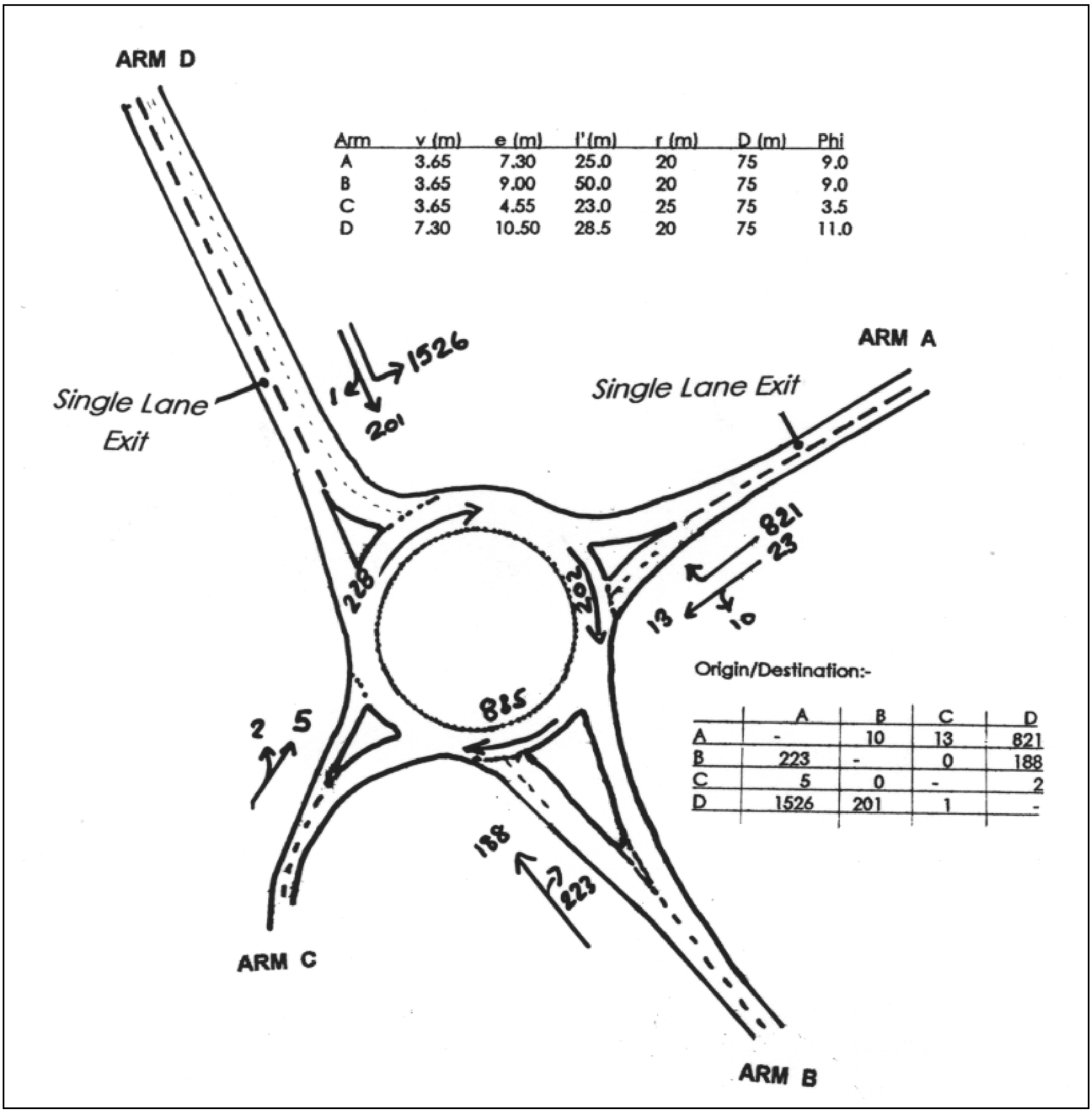
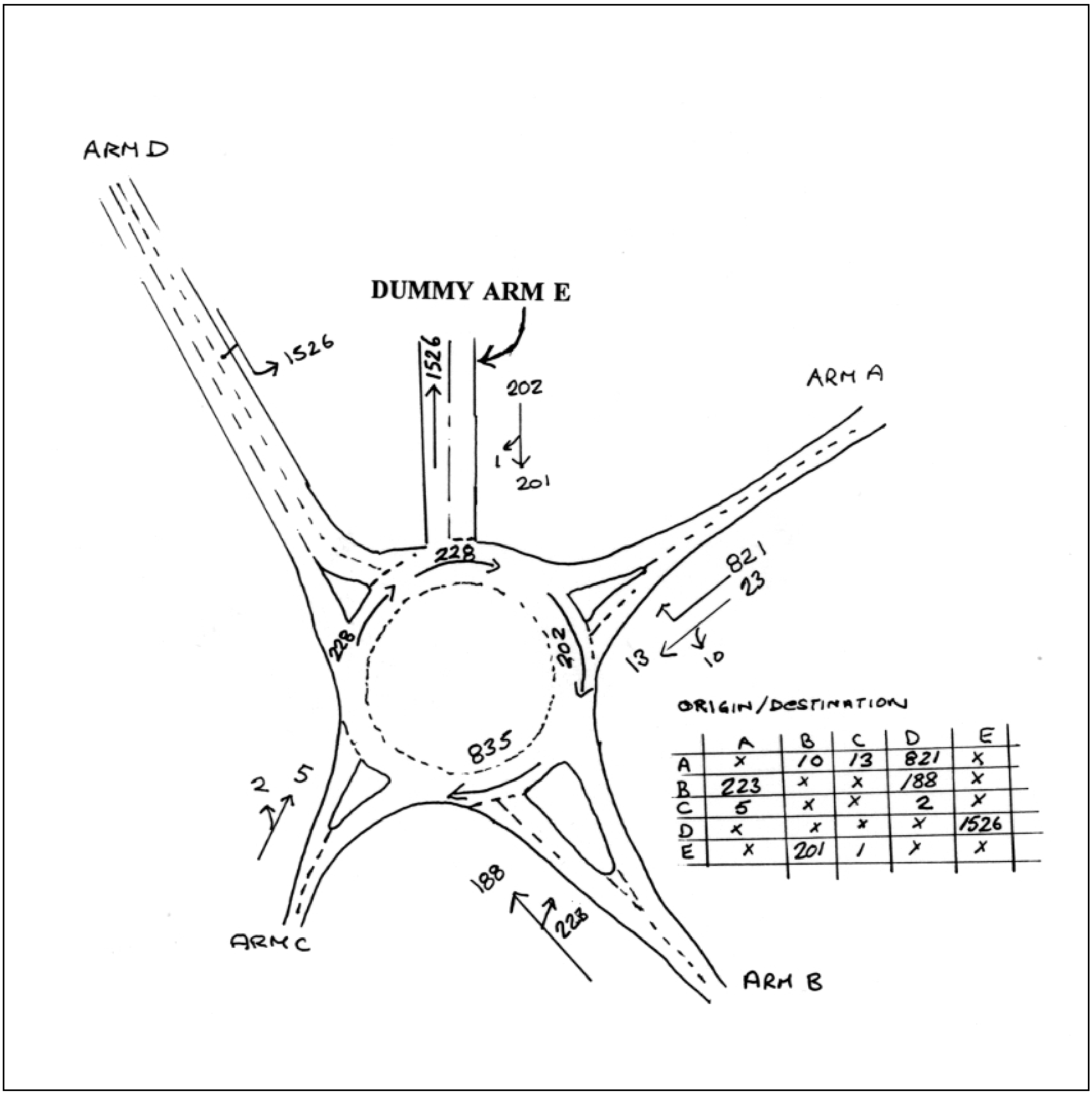



Figure 3.3 Case C – Example illustrating non and/or unequal usage of lanes and of flared sections on a roundabout approach




| | A | B | C | D | E |
|---|---|---|---|---|---|
| A | x | 10 | 13 | 821 | x |
| B | 223 | x | x | 188 | x |
| C | 5 | x | x | 2 | x |
| D | x | x | x | x | 1526 |
| E | x | 201 | 1 | x | x |

Figure 3.4 Example illustrating use of Dummy Arm E for dealing with unequal lane usage on Arm D ( see Case C – Solution (ii) )